WORK PLAN

VERIFICATION OF GROUNDWATER FATE AND TRANSPORT EVALUATION

SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

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Section 1.0

1.0 INTRODUCTION

This document presents the Work Plan for Verification of the Groundwater Fate and Transport Evaluation (Work Plan) for the South Cavalcade Superfund Site (Site) located in Houston, Texas. The location of the Site is depicted on Figure 1. This Work Plan was prepared by Key Environmental, Inc. (KEY) on behalf of Beazer East, Inc. (Beazer). Section 3.0 of this Work Plan regarding the groundwater sampling proposed to evaluate the natural attenuation of dissolved constituents in groundwater was prepared by Dr. Mark King, Ph.D. of Groundwater Insight, Ltd.

On August 5, 1997, Beazer submitted a revised Groundwater Fate and Transport Evaluation Report[1] (GFTER) to the U.S. Environmental Protection Agency (EPA) for review and approval. The GFTER presented the results of analytical groundwater fate and transport modeling conducted using existing data, where possible, and information from published technical literature as protective default values where Site-specific data were not available. The fate and transport modeling presented in the GFTER was completed by Beazer as a preliminary evaluation of whether natural attenuation processes are sufficient to meet the remedial objectives for shallow groundwater at the South Cavalcade Site. The results of the GFTER support a preliminary hypothesis that effective natural attenuation of dissolved organic constituents of interest (COI) may be occurring in the shallow groundwater zone at the Site. Table 1 lists the COIs for the shallow groundwater zone which were evaluated in the GFTER. The GFTER was approved by the EPA on August 14, 1997.

Implementation of the scope of work described herein will represent an intermediate step in the evaluation of natural attenuation in the shallow groundwater zone. The data acquired through implementation of this Work Plan will be used for further evaluation of the hypothesis that natural attenuation processes are sufficient to attenuate migration of dissolved COI in shallow groundwater to the extent necessary to satisfy the remedial objectives for shallow groundwater at the Site. If the hypothesis is supported, then Beazer will propose a plan for a future groundwater monitoring program to acquire additional time-series and spatial groundwater COI concentration

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1 Key Environmental, Inc., August 1997, Groundwater Fate and Transport Evaluation Report, South Cavalcade Superfund Site, Houston, Texas.

data for long term verification of the natural attenuation of COI in shallow groundwater. The development of the monitoring plan will be based on a comprehensive evaluation of all available information.

The natural attenuation assessment activities described herein focus only on the dissolved COIs in the shallow groundwater zone. The COIs have been detected in groundwater in the underlying discontinuous sand unit (referred to as the "intermediate zone") during previous investigations. However, as described in the EPA-approved *100% Remedial Design for the Groundwater Collection and Reinjection System and DNAPL Recovery System*[2] (100% Remedial Design), it is possible, based on existing information, that these detections are the result of improperly drilled and constructed monitoring wells. An investigation to further evaluate the possible presence of COIs in groundwater in the intermediate zone was proposed by Beazer in the EPA-approved 100% Remedial Design. Based on the findings of this investigation, Beazer may propose that a separate evaluation be conducted to determine if monitored natural attenuation may be an effective remedial approach for dissolved COI in the intermediate zone.

1.1 Site Background

1.1.1 Site Description

The South Cavalcade Site occupies approximately 66 acres of urban land approximately three miles north of downtown Houston, Texas. The site is rectangular in shape with a length of approximately 3,400 feet (in the north-south direction) and a width of approximately 900 feet (in the east-west direction). A site base map is provided as Figure 2.

The Site was operated as a wood treating plant from 1910 until 1962, with utilization of creosote and various metal salts in the wood treating processes. The wood treating process area was located in the southern portion of the Site along Collingsworth Street. Koppers Company, Inc. (Koppers), now known as Beazer, operated the wood treating facility from 1944 until closure in

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2 McLaren/Hart Environmental Engineering Corporation, December 1994. *100% Remedial Design for the Groundwater Collection and Reinjection System and Dense Non-Aqueous Phase Liquid Recovery System, South Cavalcade Superfund Site, Houston, Texas*

1962. A coal tar distillation plant was operated by Koppers on the southeastern portion of the Site from about 1944 until 1962. Since the discontinuation of these operations, several trucking firms have occupied the property.

The Site is currently occupied by three trucking firms; thus, much of the ground surface, especially in the southern and northern portions of the Site, is covered by concrete or asphalt pavement, or buildings, as shown on Figure 2. The central portion of the Site is currently undeveloped. A groundwater treatment facility is located along the eastern Site boundary in the central portion of the Site. Continued future use of the Site properties for non-residential purposes is to be expected, because deed restrictions for on-Site properties are in place and the consent agreements between EPA and the respective property owners prohibit property use for residential purposes.

Land use in the vicinity of the Site is a mixture of commercial, industrial and residential. Industrial and commercial properties are located to the east and across Collingsworth Street to the south of the Site. The North Cavalcade Superfund Site, which is also the location of a former wood treating facility, is located directly across Cavalcade Street to the north of the Site. Active rail lines immediately border the Site boundaries to the east and the west. The nearest residences are located several hundred feet to the west of the Site.

1.1.2 Site Groundwater Remedial History

In 1983, the Houston Metropolitan Transit Authority investigated the Site for potential use in the municipal mass transit system. Results of this investigation indicated localized areas of potential impact and the Site was subsequently referred to the Texas Department of Water Resources (TDWR). In April 1984, TDWR recommended to EPA that the Site be placed on the National Priorities List (NPL). In October 1984, EPA proposed that the Site be added to the NPL. The Site was formally included on the NPL in June 1986.

In March 1985, Koppers entered into an Administrative Order on Consent (AOC) to conduct a Remedial Investigation/Feasibility Study (RI/FS) at the Site. The RI/FS was completed by

Koppers in August 1988 with submittal of the *Remedial Investigation Report*[3] and the *Feasibility Study Report*[4] to EPA.

A Record of Decision (ROD) was subsequently issued by EPA in September 1988 which presented the selected remedial alternatives for Site soil and groundwater. The selected remedial alternative for groundwater included extraction and treatment of groundwater containing constituent concentrations greater than the remedial goals specified in the ROD. The ROD stipulated that "groundwater collection will continue until constituents have been recovered to the maximum extent possible", as "determined during the Remedial Action, based upon experience in operating the groundwater collection and treatment system". The ROD specified that once EPA had determined that groundwater constituents have been recovered to the maximum extent possible, groundwater collection would cease and any remaining constituents would be allowed to naturally attenuate to background levels.

The Detailed Statement of Work for South Cavalcade Site (SOW)[5] was completed by Bechtel Environmental, Inc. (Bechtel) on behalf of Beazer in May 1990. The SOW described the remedial design and remedial action (RD/RA) activities to be performed by Beazer including pilot study tasks to support the design of the selected remedies. In March 1991, Beazer entered into a Consent Decree[6] with EPA for implementation of the RD/RA activities specified in the SOW. The SOW was subsequently incorporated into the EPA-approved *Remedial Design Work Plan* (RDWP)[7] prepared by Bechtel on behalf of Beazer, dated March 1992.

3 Keystone Environmental Resources, Inc., July 1988. *Final Report - Remedial Investigation, South Cavalcade Site, Houston, Texas.*

4 Keystone Environmental Resources, Inc., August 1988. *Feasibility Study , South Cavalcade Site, Houston, Texas.*

5 Bechtel Environmental, Inc., May 1990. *Detailed Statement of Work for South Cavalcade Site, Houston, Texas.*

6 U.S. Environmental Protection Agency, March 1991. *South Cavalcade CERCLA RD/RA Consent Decree, Civil Action No. H-90-2406.*

7 Bechtel Environmental, Inc., March 1992. *Remedial Design Work Plan, South Cavalcade Site, Houston, Texas.*

Pilot study tasks conducted to support the groundwater remedial design included a groundwater collection well pilot study, groundwater recovery trench pilot study and groundwater treatment system pilot study. Pilot study tasks were completed in October 1993. The *100% Remedial Design* was submitted to EPA in December 1994 and was subsequently approved.

Implementation of the groundwater remedial action was initiated in June 1995 in accordance with the EPA-approved *Remedial Action Work Plan* (RAWP)[8] dated May 1995 and associated support documents. One DNAPL recovery well (RWN-4) and four groundwater collection wells (RWN-1, RWN-2, RWN-3 and RWN-5) were installed within Groundwater Remedial Action Area (GRAA) 1 located in the northern section of the Site. One DNAPL recovery well (RWS-5) and three groundwater collection wells (RWS-3, RWS-4, and RWS-6) were installed within GRAA 2, which includes the area formerly occupied by the coal tar distillation plant. Two combined groundwater collection/DNAPL recovery wells (RWS-1 and RWS-2) were installed within GRAA 3, which includes the area formerly occupied by the wood treating process area.

Start-up of the groundwater collection and DNAPL recovery components of the groundwater remedy was conducted in September 1995, following completion of the groundwater treatment plant modifications. In an EPA letter dated October 6, 1995[9], EPA indicated that "there is some question as to whether EPA will continue to apply the current remedial action goals [i.e., the remedial goals specified in the ROD issued in 1988] to groundwater cleanup." This direction was taken in response to a July 31, 1995 EPA memorandum[10] directing a policy favoring applicable and relevant and appropriate requirement (ARAR) waivers at sites where it is technically impracticable to remediate groundwater to Federal or State standards. As provided by the October 6, 1995 EPA letter and in accordance with an agreement between EPA and

8 Dames and Moore, May 1995. *Final Remedial Action Work Plan, South Cavalcade Site, Houston, Texas.*

9 U.S. Environmental Protection Agency, October 6, 1995. *South Cavalcade Street Superfund Site Groundwater Exposure Assessment Work Plan, September 1996, EPA Review Comments.*

10 U.S. Environmental Protection Agency, July 31, 1995, *Memorandum from Elliot Laws, Assistant Administrator, to Regional Administrators Region I - X Regarding Superfund Groundwater RODs: Implementing Change This Fiscal Year.*

Beazer, groundwater collection and treatment has been delayed pending determination of the potential inapplicability of the groundwater remedial goals specified in the ROD. Operation of the DNAPL recovery component of the groundwater remedy is currently ongoing.

DNAPL recovery operations were conducted in conjunction with groundwater pumping during November and December 1995 as start-up/shakedown of the groundwater treatment system was completed. In January 1996, operation of the DNAPL recovery system in the passive mode of operation (i.e. collection of DNAPL without groundwater pumping to increase hydraulic gradients) was initiated in accordance with the EPA-approved 100% Remedial Design. Evaluation of the DNAPL recovery data collected through June 1996 in accordance with the statistical protocol (i.e., zero-slope analysis) specified in the *Groundwater Extraction System Performance Monitoring Plan* (GESPMP)[11] indicated that DNAPL had been recovered to the "maximum extent possible" under the passive mode of operation.

As a result and in accordance with the EPA-approved 100% Remedial Design, DNAPL recovery, with groundwater extraction to enhance hydraulic gradients, was initiated in one GRAA (GRAA 3) to evaluate the effectiveness and practicability of this enhancement prior to its use in the other GRAAs. Evaluation of the DNAPL recovery data collected in GRAA 3 from July through September 1996 indicated that groundwater extraction (at a pumping rate of 0.3 gpm from individual recovery wells) appeared to enhance DNAPL recovery in Wells RWS-1 and RWS-2. Based on this observation, DNAPL recovery with groundwater extraction to enhance hydraulic gradients was initiated in GRAAs 1 and 2 in October 1996. Currently, DNAPL recovery with groundwater extraction is being conducted in all three GRAAs. As of this time, approximately 800 gallons of DNAPL have been removed from the shallow water-bearing zone. Beazer will continue operation of the DNAPL Recovery System in the gradient enhanced mode, in accordance with the EPA-approved RAWP and in accordance with applicable EPA Guidance,

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[11] KEY Environmental, Inc., August 1995. *Groundwater Extraction System Performance Monitoring Plan, South Cavalcade Superfund Site, Houston, Texas.*

such as the *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration*[12].

In addition to the ongoing DNAPL recovery operation, Beazer has been conducting annual groundwater monitoring since March 1993 in two deeper monitoring wells located in the vicinity of the Site, as stipulated in the ROD. This activity is independent of the natural attenuation assessment for shallow groundwater and is subject only to the applicable provisions of the ROD and EPA approved RDWP.

1.1.3 Site Conceptual Model Overview

A detailed Site conceptual model was developed and presented in Section 2.0 of the GFTER. An overview of the Site conceptual model presented in the GFTER is presented in the following paragraphs, to facilitate an understanding of existing Site conditions pertinent to the subject groundwater fate and transport evaluation.

The COIs have been detected in groundwater within the shallow fluvial-deltaic deposits, comprising intermittent, interbedded fine sand, silt, and clay that extend from the ground surface to a depth of approximately 22 ft-bgs. The water table typically occurs within this unit at a few feet below the ground surface. Groundwater flow within the aquifer is generally in a westerly direction. Average horizontal hydraulic conductivities for the northern and southern sections of the Site are 7.8×10^{-3} cm/sec (8,070 ft/year) and 1.6×10^{-3} cm/sec (1,655 ft/year), respectively. A downward vertical hydraulic gradient has been measured between the shallow aquifer and the underlying discontinuous sand unit (referred to as the intermediate zone in the 100% Remedial Design), which lies at a depth of 40 to 50 feet below ground surface. COIs have been detected in groundwater in some instances in this discontinuous sand unit. However, as described in 100% Remedial Design and previously in this document, it is possible that these detections are the result of improperly drilled and constructed monitoring wells. An investigation to further evaluate the possible presence of COIs in groundwater in the intermediate zone was proposed by

12 U.S. EPA, September 1993, *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration*, EPA/540-R-93-080.

Beazer in the EPA-approved 100% Remedial Design. For this reason, the shallow aquifer is considered the unit of interest for the natural attenuation evaluation addressed in this Work Plan.

The COIs have been identified to be PAH compounds and BTEX based on the analytical results of groundwater samples collected from within the shallow zone. These constituents are typical COIs for sites where wood treating operations have been conducted using creosote as a preservative. The PAH compounds are the primary components of creosote solutions, while BTEX is associated primarily with petroleum products used as carrying agents in creosote wood treating processes.

Site data indicate that the extent of these constituents in groundwater is primarily limited to the shallow unconfined aquifer. The source areas for these COIs are the locations at the Site where DNAPL has been detected. No addition to, or movement of, DNAPL is anticipated over time, due to the strong indications that the DNAPL has achieved a static distribution within the shallow aquifer. However, the areas containing immobile free-phase or residual DNAPL are anticipated to be a long term source for dissolved phase COIs within shallow groundwater.

COIs dissolve from the DNAPL into the groundwater as a function of the effective solubilities. Migration of COIs occurs in the general groundwater flow direction due to dispersion and advection. Attenuation mechanisms such as dispersion, adsorption and biodegradation cause COI concentrations to decrease with migration away from the source. The PAH compounds have low aqueous solubilities and are readily attenuated by sorption to naturally occurring organic carbon in the aquifer matrix. BTEX constituents have moderate solubilities, however, they are more readily attenuated by biodegradation.

The downgradient extent of COI in the southern area may be estimated using the data from monitoring well MW-08, which is located approximately 320 feet downgradient of the southwestern Site boundary. COI concentrations measured in groundwater samples collected from this well are less than applicable standards. In the northern area, monitoring well MW-01, is located approximately 260 feet downgradient of the PDSA. Benzene concentrations in this well slightly exceed the remedial goal specified in the ROD. To verify the downgradient extent of the dissolved plume in the northern area, an additional monitoring well is proposed at an off-site location further downgradient of MW-01.

The nearest potential future off-site groundwater exposure points are protectively assumed to be approximately 400 feet downgradient from the potential constituent source areas. Consequently, these hypothetical exposure points were used in the fate and transport model to evaluate the effectiveness of natural attenuation for preventing potential future exposure to constituents in groundwater. The protective nature of the assumed 400-foot distance to the nearest possible future receptor is indicated by the following observations:

- water in the local area is supplied by the municipal system;
- the quality of shallow groundwater is poor due to naturally occurring conditions;
- groundwater yield from the shallow aquifer is expected to be low; and,
- no groundwater withdrawal wells within the shallow aquifer are known to exist within one mile of the site.

1.1.4 Groundwater Fate and Transport Evaluation Results

The fate and transport evaluations were conducted using protective assumptions regarding constituent transport, natural attenuation processes, and potential future use of shallow groundwater. These assumptions were intended to ensure that the potential for future exposure to COIs in groundwater is not underestimated. The significant results of the GFTER are summarized below:

- "Incorporation of biodegradation effects into the analytical model simulations is justified by the demonstration and documentation of intrinsic biodegradation of dissolved creosote constituents in groundwater at several similar Sites. Additionally, the reduced concentrations of an electron acceptor (sulfate) and the relatively stable observed constituent concentrations over time also support incorporation of biodegradation effects into the fate and transport evaluation. Also, the benzene concentrations predicted by the Ogata-Banks analytical simulations using the best case input transport parameter values are significantly greater than the actual benzene concentrations determined through laboratory analysis of groundwater samples. Thus, the reduced concentrations of benzene observed at the Site downgradient of the constituent source areas, as demonstrated by previous laboratory analyses of groundwater samples, cannot be solely attributable to adsorption and dispersion processes alone. These findings indicate that other processes, such as biodegradation, are in fact acting to retard the migration or naturally attenuate COIs in the shallow aquifer."

- "The results of the worst case BIOSCREEN simulations demonstrate effective natural attenuation of COIs within a short distance of potential constituent source areas and well before groundwater concentrations greater than the ROD remedial goals or TNRCC MSCs are realized at the nearest hypothetical future groundwater withdrawal well."

- "The results of the BIOSCREEN simulations using protectively assumed constituent half-life values indicate that the COIs in the shallow groundwater have already achieved a steady state or equilibrium distribution. These simulations indicate that future migration or increasing concentrations of COI will not occur. The simulations were completed using the transport input parameter values and degradation rates which favor the prediction of greater migration distances and constituent concentrations. Thus, these simulations are considered to represent a protective prediction of the steady state distribution of dissolved COIs in groundwater. This conclusion is supported by a comparison of the 1986-87 groundwater concentration data with data obtained from the supplemental groundwater sampling completed in November 1993. Comparison of these data indicates stable or decreasing constituent concentrations between 1986-87 and 1993."

- "The results of the worst case fate and transport simulations under non-pumping conditions predicted concentrations of the more mobile and biodegradable COIs several orders of magnitude greater than the actual concentrations determined through previous groundwater analysis. Despite the use of transport parameter values in this simulation which favor the prediction of greater migration distances and constituent concentrations, several of the higher molecular weight PAH compounds were demonstrated to be immobile and sufficiently attenuated by this overly protective evaluation."

The results of the fate and transport evaluations indicated that implementation of a monitored natural attenuation remedy for groundwater at the South Cavalcade Site is feasible. The data collection and information gathering activities described in this Work Plan are intended to to further evaluate the hypothesis presented in the GFTER.

1.2 Purpose of Work Plan / Project Objectives

This Work Plan defines investigative activities that will provide additional field data and site-related information necessary to verify the conclusions of the GFTER and to determine the overall feasibility of a monitored natural attenuation remedy for shallow groundwater at the South Cavalcade Site. If these data support the conclusion presented in the GFTER that a monitored natural attenuation remedy will be effective, then a groundwater monitoring program will be developed to acquire the necessary time-series and spatial groundwater concentration data to document the effective natural attenuation of dissolved COI for groundwater in the shallow zone.

This Work Plan was developed to evaluate monitored natural attenuation in a manner consistent with the following definition developed by the EPA Office of Research and Development and Office of Solid Waste and Emergency Response[13]:

> "The term "monitored natural attenuation", as used in this Directive, refers to the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remedial objectives within a time frame that is reasonable compared to that offered by other more active methods. The "natural attenuation processes" that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in situ processes

13 U.S. EPA, November 1997, *Use of Monitored Natural Attenuation At Superfund, RCRA Corrective Action, and Underground Storage Tank Sites,* Office of Solid Waste and Emergency Response Directive 9200.4-17.

include biodegradation; dispersion; dilution; sorption; volatilization; and chemical or biological stabilization, transformation, or destruction of contaminants."

The specific objective for monitored natural attenuation at the South Cavalcade Site are based on potential risk to human health and the environment due to COIs dissolved in groundwater. Specifically, the monitored natural attenuation objective states that this approach will be deemed to provide acceptable mitigation of risk if current or future dissolved COI concentrations do not exceed the ROD remedial goals for groundwater at hypothetical future downgradient exposure points. Further, the hypothetical groundwater exposure point is to be considered the hypothetical location of a future groundwater extraction well, and the increase in the rate of downgradient groundwater movement in the vicinity of the well due to pumping is to be considered in the analysis. In order to meet the objective, monitored natural attenuation must eventually cause dissolved COI distributions to stabilize or recede before the hypothetical downgradient exposure point is reached.

As described in the EPA-approved GFTER, the hypothetical exposure points were selected as the nearest non-industrial property downgradient of the Site. In the Northern Area, the area between the Site boundary and the hypothetical location of future groundwater use is occupied by a right-of-way for an active rail line and a public roadway. In the Southern Area, the area between the Site boundary and the hypothetical location of future groundwater use is occupied by an active petroleum storage facility, a right-of-way for an active rail line and a public roadway.

For the analysis conducted in the GFTER, it has been assumed that input concentrations from the source to the plume are constant, which further assumes that the source does not become depleted over time. This assumption generally imparts a higher degree of protectiveness to the analysis than the assumption of source depletion, since it provides the greatest potential for plume migration. The constant source assumption is reasonable with respect to creosote DNAPL sources, such as those at South Cavalcade: the relatively low solubilities of most of the constituent compounds will provide a slow rate of mass transfer from the source to groundwater and a correspondingly slow rate of source depletion. Consequently, the emphasis of the current investigation is on dissolved phase natural attenuation processes, rather than natural attenuation of the DNAPL sources.

1.3 Technical Approach

The approach used herein is guided by EPA Data Quality Objectives Guidance[14] which advocates a step-wise process to the development of sampling programs to ensure that the data collected are appropriate to meet the project objectives. This approach involves a decision rule process which establishes pre-determined evaluation criteria to which collected information are compared. Upon comparison and evaluation of the data, the decision rule process is followed, by which a resulting action/decision is methodically determined. In conjunction with the comparison of data to pre-determined criteria, technical and practical judgement will be utilized to ensure that the project objectives are attained and that appropriate decisions are made consistent with project-specific requirements. The field implementation of this Work Plan will be dependent upon the real-time interpretation of field data (e.g., gas chromatograph [GC] groundwater field screening results and potentiometric data). These interpretations will guide sampling activities to ensure that a sufficient quantity of data is collected at appropriate locations to satisfy project objectives.

In addition to the evaluation of the real-time field data, Beazer will complete a review of available historic information to refine the current understanding of the limits of potential on-site constituent sources, potential constituent migration pathways and extent of dissolved phase plumes, as agreed at the July 2, 1998 meeting with EPA. If appropriate, the findings of this task will serve as the basis for development of supplemental characterization activities to be completed in conjunction with the investigation proposed in the Work Plan. The purpose of the supplemental characterization activities, if necessary, will be to assess if any other dissolve phase plumes (other than the two plumes to be addressed under the Work Plan) exist which may potentially migrate from the Site to the locations of hypothetical potential future groundwater receptors.

The conclusions presented in the GFTER are based on: 1) Site conditions as described by the Site conceptual model, and 2) representative and protective literature values used as input for the groundwater fate and transport modeling. The proposed data collection and information

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[14] EPA, October 6, 1993, *Guidance for Planning for Data Collection in Support of Environmental Decision Making Using the Data Quality Objectives Process, Interim Final*, EPA QA/G-4.

gathering efforts will evaluate the GFTER conclusions by collecting site-specific information relative to these conditions and values. This information focuses mainly on three primary lines of natural attenuation evidence:

- Direct observation or interpretation of plume status (i.e., advancing, stable, or receding);
- Intrinsic biodegradation; and,
- Sorption to aquifer solids.

If the information gathered pursuant to the implementation of this Work Plan support the hypothesis presented in the GFTER (i.e., monitored natural attenuation is a feasible remedial approach for shallow groundwater), then a groundwater monitoring program will be developed to acquire sufficient spatial and time-series data to verify the effective natural attenuation of COIs in shallow groundwater.

Standard operating procedures (SOPs) will be followed in the implementation of the scope of work. Specific SOPs applicable to the investigative activities proposed in this Work Plan are provided in Appendix A and listed below:

- *Monitoring Well Sampling;*
- *Sampling Equipment Decontamination*;
- *Chain of Custody*;
- *Subsurface Soil Sampling*;
- *Sample Handling, Preservation Packaging and Shipping;*
- *Depth to Groundwater and NAPL Measurements*; and,
- *DNAPL Sample Collection.*

1.4 Organization of Work Plan

The data collection component of the Work Plan is generally divided into two types of tasks: those conducted to evaluate modeling boundary conditions and input parameters (Section 2.0), and those intended to evaluate plume migration (Section 3.0). These sections are organized in a manner that is generally consistent with EPA Data Quality Objectives Guidance, and include the following subsections: Objectives, Input Data, Sampling Locations and Frequencies, and Decision Rules. Section 4.0 describes the anticipated format of the Report of Findings to be prepared by Beazer to summarize the results of the data collection and information gathering activities. Section 5.0 presents the proposed schedule for implementation of the scope of work.

2.0 SAMPLING TO VERIFY MODELING ASSUMPTIONS

The overall objective of this component of the Work Plan is to evaluate whether modeling assumptions (i.e., model input parameter values and boundary conditions) used in the GFTER, and the information used in development of the Site conceptual model are appropriate and representative of the Site conditions. Additional site-specific information pertaining to COI source physical properties, groundwater flow, groundwater usage and COI sorption will be collected. Specific aspects of the fate and transport evaluation to be further examined in this component of the study include:

- Hydraulic gradients and groundwater flow directions (Section 2.1);
- Aquifer organic carbon content (Section 2.2);
- Physical properties (grain size distribution, porosity, and bulk density) of the aquifer matrix (Section 2.3);
- DNAPL physical properties presented in the Site conceptual model (Section 2.4); and,
- Local groundwater usage information presented in the Site conceptual model (Section 2.5).

The GFTER assumed the extent of DNAPL is limited to the potential DNAPL source areas (PDSA's) shown on Figure 3. DNAPL was considered immobile because any releases of DNAPL to the subsurface were eliminated at a minimum of 36 years ago when wood treating operations were discontinued. The potential for the DNAPL source to advance further in the direction of groundwater flow in the shallow zone will be assessed through the implementation of a future monitoring program, which may include the installation and monitoring of "sentry wells" in the area downgradient of the PDSA's. Further evaluation of the extent of DNAPL will not be conducted at this point in the natural attenuation demonstration for the following reasons:

- If the DNAPL source extends further downgradient than currently assumed, then natural attenuation processes must be occurring to a greater degree than predicted by the GFTER, to explain the observed reduction in COI concentrations downgradient of the PDSA's;

- Modeling conclusions regarding the downgradient extent of the dissolved plume are not sensitive to the width of the PDSA's in the direction of perpendicular to groundwater flow because the fate and transport evaluation presented in the GFTER assumed negligible transverse dispersion; and,

- The width of source areas may be inferred from information obtained from downgradient transect borings (See Section 3.0 of this Work Plan).

Hydraulic gradient and aquifer organic carbon content were chosen for further examination, because these parameters were identified in the sensitivity analyses presented in the GFTER as being parameters which exhibit a relatively significant influence on the predicted extent of COI migration. Other parameters such as hydraulic conductivity and dispersivity were not identified for further examination for reasons described in the following paragraphs.

Existing hydraulic conductivity data were determined from pumping tests performed at the Site[15] [16] and are considered representative. According to Wiedemeier et al.[17], the most reliable hydraulic conductivity data are generally attained through pumping tests. Site-specific, upper-end, hydraulic conductivities were extensively used in the initial groundwater fate and transport modeling presented in the GFTER, in order to ensure that the model predictions were protective. This range of hydraulic conductivities is based on values determined for shallow, Unit 1 wells, including wells screened exclusively within the Silty Sand zone of Unit 1. The GFTER provides additional detail regarding the selection of this input parameter.

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15 Keystone Environmental Resources, Inc., July 1992, Extraction Well Pilot Study Report, South Cavalcade Site, Houston, Texas.

16 McLaren/Hart Environmental Engineering Corporation, October 1993, Groundwater Collection Trench Pilot Study Report, South Cavalcade Superfund Site, Houston, Texas.

17 Wiedemeier, T., Wilson, J.T., Kampbell, D.H., Miller, R.N., and Hansen, J.E., 1995, Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater.

With respect to dispersivity parameters, longitudinal dispersion was addressed through sensitivity analysis in the GFTER. Transverse dispersivities (horizontal and vertical) were addressed in the GFTER by assuming that they are negligible, which is the most conservative approach (i.e., promotes downgradient constituent migration).

2.1 Hydraulic Gradients and Groundwater Flow Directions

A total of 28 rounds of groundwater potentiometric surface elevation data were collected from February 1983 to November 1987, and are presented in the Final Report - Remedial Investigation. These data were used in the calculation of hydraulic gradients presented in the GFTER. Based on the quantity of data available, the calculated hydraulic gradients are considered representative of Site conditions. These data represent a substantial database for evaluating groundwater flow direction trends over time, which are identified in the Final Report - Remedial Investigation as being relatively constant. They will be compared with groundwater potentiometric surface elevation data to be measured in accordance with this Work Plan.

2.1.1 Objectives

Current potentiometric data will be acquired and compared with previous data to evaluate whether the hydraulic gradient data used in the fate and transport model are appropriate and representative of Site conditions. The magnitude of the hydraulic gradient and direction of groundwater flow will be determined for the northern and southern areas of the Site.

This task will be completed and the resultant data evaluated prior to finalizing downgradient sampling locations described in subsequent sections of this Work Plan. Should this evaluation indicate a difference from groundwater flow directions observed in the past, the proposed sampling locations will be re-evaluated and will be adjusted as necessary. This measure will provide further confidence that sufficient representative data necessary to satisfy project objectives will be acquired.

2.1.2 Evaluation Data

Groundwater potentiometric measurements will be obtained for the shallow silty sand unit using an electronic water level indicator tape graduated in hundredths of feet. Depth to groundwater at individual monitoring points will be converted to geodetic elevations and these data will be used to contour the potentiometric surface. This surface will then be utilized in the determination of groundwater flow directions and calculation of hydraulic gradients for each of the areas designated on Figure 3.

2.1.3 Sampling Locations and Frequency

The current horizontal hydraulic gradient in the northern and southern areas of the Site will be determined by performing a single round of groundwater potentiometric measurements in all shallow Site monitoring wells and piezometers, as presented on Figure 4. These wells and piezometers cover the same Site areas where Site potentiometric conditions were previously evaluated; however, additional data points (i.e., piezometers installed as part of the groundwater Remedial Action) are now available to refine the estimation of groundwater flow directions and gradients. These wells and piezometers are screened in the upper silty sand silt unit, and are therefore appropriate for collection of hydraulic gradient data pertaining to the groundwater fate and transport evaluation.

Implementation of this task will require that operation of the DNAPL recovery system be suspended to ensure that the data are representative groundwater flow direction under non-pumping conditions. Beazer anticipates that the DNAPL recovery system operation will be suspended from approximately one week prior to the measurement of groundwater levels until completion of the field work for this task. This one week duration is estimated to be sufficient recovery time, based on aquifer recovery information presented in the Groundwater Collection Trench Pilot Study Report. In addition, the treatment plant operator will monitor groundwater levels following shut down. The monitoring results will be reviewed to determine the degree of recovery completion over time. Prior to producing a groundwater potentiometric surface elevation contour map from the newly measured groundwater elevation data, groundwater monitoring well/piezometer construction diagrams will be reviewed to identify monitoring points with inconsistent screened depths and intervals. Based on this review, data from inappropriate monitoring wells/piezometers may be eliminated for use in determining the potentiometric surface in the silty sand unit.

2.1.4 Decision Rules

A range of hydraulic gradient values, for non-pumping conditions (1.76×10^{-3} ft/ft to 5.88×10^{-3} ft/ft), was utilized in the GFTER fate and transport model. This range, based on data presented in the Final Report - Remedial Investigation[18], will serve as the evaluation criterion for comparison with area-specific hydraulic gradients estimated as part of this investigation. If the area-specific hydraulic gradients calculated from current data are within this range, then the hydraulic gradient data used in the fate and transport model will be considered representative and appropriate. If the estimated hydraulic gradients from the current investigation are less than 1.76×10^{-3} ft/ft, then the model will be declared protective with respect to the hydraulic gradients used as input to the model. If they are greater than 5.88×10^{-3} ft/ft, then the model will be re-run utilizing the area-specific hydraulic gradient from the current investigation. This approach is suggested to keep the model protective.

2.2 Organic Carbon Concentration

2.2.1 Objectives

In the GFTER fate and transport modeling, COI sorption was estimated on the basis of the fraction of organic carbon (f_{oc}) in the aquifer matrix. A protective value (i.e., a value intended to simulate the maximum expected degree of COI migration) for this parameter was selected based on literature values presented by Karickhoff et al.[19] for similar aquifer materials. The sensitivity analysis presented in the GFTER indicates that f_{oc} is a relatively sensitive parameter with respect

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18 Keystone Environmental Resources, Inc., July 1988, *Final Report - Remedial Investigation, South Cavalcade Site, Houston, Texas.*

19 Karickhoff, S.W., Brown, D.S., Scott, T.A., 1979, *Sorption of Hydrophobic Pollutants of Natural Sediments*, Water Research, v. 13, p. 241-248.

to constituent migration rates. Consequently, organic carbon data will be obtained for comparison to values used in the fate and transport model.

2.2.2 Evaluation Data

Soil samples will be collected from within the aquifer in the southern and northern areas of the Site, and will be submitted to the subcontracted analytical laboratory for analysis of total organic carbon (TOC) by EPA Method 9060 modified for soil. These sampling requirements are summarized in Table 1. The measured TOC concentrations will be converted to f_{oc} for the purpose of comparison to the f_{oc} values used in the fate and transport model.

2.2.3 Sampling Locations and Frequency

Soil samples for TOC analysis will be collected to characterize aquifer sorption properties in the vicinity of the plumes. The proposed sampling points are located along two transects of direct-push soil borings oriented transverse to the direction of groundwater flow, as indicated in Figures 5 and 6, respectively, and discussed in Section 3.1. Collection of four TOC samples is proposed in each of the two Site areas of interest. Samples will be collected at boring locations that are determined to be outside of the plume core, as defined in Section 3.1. A preliminary analysis of the potential contribution of COIs to soil sample TOC indicates that the contribution is minimal where DNAPL is absent (i.e., where COIs are only present in dissolved phase). If necessary, the final report will present a site-specific analysis of the COI contribution to TOC if dissolved phase COI are detected in the groundwater samples collected from the TOC sampling locations.

In each of the areas, two discrete samples of the silty sand unit will be collected over two-foot intervals at two direct-push boring locations. One sample will be selected from the upper half of the silty sand unit and one from the lower half. All samples for TOC analyses will be collected from the shallow, saturated, silty sand unit previously referred to as Unit 1 in the RI Report (Figure 7), as confirmed by continuous stratigraphic logging starting at a depth of 2 ft-bgs . Sample collection will be performed using direct-push techniques (e.g., Geoprobe) using split-barrel or core samplers.

2.2.4 Decision Rules

The f_{oc} used in the GFTER fate and transport model ranged from 8.6×10^{-4} to 5.7×10^{-3} and this range will serve as the evaluation criterion. A 95% confidence interval will be calculated for each area (i.e. northern and southern Site areas) using f_{oc} data obtained during this investigation. This range will be compared to that used in the GFTER and overlap of the ranges will indicate that the f_{oc} range utilized in the modeling is appropriate and representative. If the lower limit of the 95% confidence interval is greater than 5.7×10^{-3}, then the model will be declared protective with respect to constituent adsorption. If the upper limit of the 95% confidence interval is less than 8.6×10^{-4}, then the model will be re-run utilizing the mean organic carbon content determined from the field investigation. If variability in the collected organic carbon data renders a 95% confidence interval misleading, or the decision rule as it stands offers no technical or practical value within the context of a 95% confidence interval, then an alternative data evaluation, agreed upon by EPA and Beazer, will be pursued.

2.3 Physical Properties of the Aquifer Matrix

2.3.1 Objectives

The objective of measuring physical properties of the aquifer matrix is to evaluate whether various assumptions and parameter values used in the fate and transport modeling are sufficiently representative. Specifically, grain size distribution data from multiple locations within an aquifer provide an indication of the range of materials comprising the aquifer matrix. Aquifer matrix porosity and bulk density measurements can be directly input into a fate and transport model in the calculation of groundwater seepage velocity and constituent retardation factors, respectively. These data will provide for a comparison between actual aquifer physical properties and selected values utilized in modeling efforts presented within the GFTER.

2.3.2 Evaluation Data

Soil samples will be collected from within the aquifer in the southern and northern areas of the Site, and will be submitted to a subcontracted analytical laboratory for analysis of grain size and bulk density by ASTM D422 and ASTM D2937, respectively. Particle specific gravity will be measured using ASTM D854 to allow for the calculation of porosity from the bulk density data. These sampling requirements are summarized in Table 2. The measured parameters will be utilized for the purpose of assessing the range of materials comprising the aquifer matrix, and for comparison to selected input parameter values utilized in the GFTER fate and transport modeling. Grain size data will be evaluated to provide a qualitative comparison to hydraulic conductivities utilized in the model.

2.3.3 Sampling Locations and Frequency

Samples of the shallow aquifer matrix will be collected for measurement of physical properties. Samples collected for measurement of aquifer properties will be collected at the same locations and depths as the soil samples for TOC analysis as indicated on Figures 5 and 6. However, in order to obtain sufficient soil sample volume, multiple direct push advances may be necessary within a few feet of the designated sampling locations.

Two sampling locations (corresponding to TOC sampling locations) are proposed in each of the two Site areas of interest. For each boring, two discrete samples of the silty sand unit, collected over two-foot intervals, will be submitted for laboratory analysis. One sample will be selected from the upper half of the silty sand unit and one from the lower half. All samples for physical analyses will be collected from the shallow, saturated, silty sand unit previously referred to as Unit 1 in the RI Report (Figure 7), as confirmed by continuous stratigraphic logging starting at a depth of 2 ft-bgs. Sample collection will be performed using direct-push techniques (e.g., Geoprobe) using split-barrel or core samplers.

2.3.4 Decision Rules

Porosity and bulk density measurements from field samples will be compared to porosity and bulk density values used in the GFTER fate and transport modeling. Specifically, a 95% confidence interval will be calculated for both porosity and bulk density data acquired from the field investigation. If the respective values for porosity and bulk density used in the fate and transport modeling are within the range of the 95% confidence interval, then the modeling will be considered representative of Site conditions.

If the porosity value utilized in the fate and transport modeling is less than the lower end of the 95% confidence interval, then the model will be declared protective, as lower porosity facilitates constituent transport[20]. If the porosity value entered into the model is greater than the upper end of the 95% confidence interval, then the model will be re-run using the geometric mean porosity acquired through the field activities.

In the case of bulk density, greater bulk density values result in greater retardation factors. Therefore, if the bulk density value used in the fate and transport modeling is less than the lower end of the 95% confidence interval, then the model will be declared protective. If the modeled bulk density from the GFTER is greater than the upper end of the 95% confidence interval, then the model will be re-run using the geometric mean bulk density acquired through the field activities.

2.4 DNAPL Properties

2.4.1 Objectives

The objective of evaluating DNAPL properties is to evaluate whether the assumption of negligible DNAPL mobility, as described in the Site conceptual model, is appropriate. The inferred extent of DNAPL, depicted in Figure 3, is based on the following information:

- The observed presence of a separate-phase product layer in Site monitoring wells;
- The results of chemical analysis of soil and groundwater samples collected within the shallow aquifer;

[20] U.S.EPA, June 3, 1997, Memorandum regarding South Cavalcade Street Superfund Site, Groundwater Fate and Transport Evaluation Report, Comments, submitted to Beazer East, Inc.

- The location of the former plant process areas where the potential for past releases of DNAPL exists;

- The configuration of the top of the basal confining unit for the shallow aquifer; and,

- The typical low density and high viscosity which limits the mobility of creosote DNAPL.

This approach was chosen to delineate the inferred limits of the PDSA's over analytical modeling methods (e.g., Cohen and Mercer, 1993) because many of the site-specific data required for effective application of such models are not available. Consequently, Beazer considers the delineation of DNAPL based on actual data and, future monitoring of DNAPL sentry wells, if necessary, to be a more reliable approach for evaluation of natural attenuation at the subject site.

The PDSA's shown on Figure 3 closely resemble the former plant process areas. This is primarily due to two types of observations:

- The location of the former plant process areas encompass, for the most part, the locations of monitoring wells where DNAPL has been observed; and,
- The results of soil and groundwater samples collected within the shallow aquifer in these areas are indicative of the possible presence of DNAPL.

As indicated at a July 2, 1998 meeting with EPA, Beazer will conduct a comprehensive review of existing information, as it pertains to DNAPL presence (i.e, visual observations of DNAPL in the shallow zone, as noted on the boring logs), to refine the delineation of the source areas. Supplemental characterization activities will be performed, if necessary to satisfy project objectives, based on the refinement of the source area limits.

The Site conceptual model assumes that the density and viscosity of DNAPL at the Site are similar to typical values reported for creosote in the literature. These properties (relative low density and high viscosity) limit the lateral and vertical migration of creosote DNAPL in the subsurface. Releases of DNAPL to the subsurface are not believed to have occurred in the time since wood treating operations at the Site were discontinued over 35 years ago. Therefore, the DNAPL is assumed to have attained a static distribution in the subsurface. Based on this information, the migration of DNAPL beyond the limits delineated on Figure 3 is not expected to occur in the future. However, this expectation would be confirmed on an ongoing basis, as part of the future monitoring program that would be proposed if the current study provides support for monitored natural attenuation at the subject site. In such a program, "sentry wells" may be installed at the downgradient boundary of the PDSA's to document that the DNAPL in the shallow zone is not migrating toward the location of the hypothetical future receptor.

In the Site conceptual model, it has been assumed that the DNAPL exhibits low mobility. This assumption was used in the GFTER as the basis for development of the model boundary conditions with respect to the limits of the potential DNAPL source areas (PDSAs). It has further been assumed that this immobile DNAPL is a continuous source of dissolved-phase COIs in the areas defined as PDSAs, as indicated on Figure 3.

Physical DNAPL properties will be measured to evaluate whether they are consistent with the GFTER Site conceptual model assumption of an immobile source. Additionally, field observations and sample analytical data from direct-push borings completed downgradient of the PDSAs may also be used to qualitatively evaluate the low mobility and estimated limits of DNAPL in the shallow zone.

Should DNAPL be observed in any of the sampling points located downgradient of the PDSA's, then appropriate modifications to the sampling program will be made, as necessary, to meet the project objectives. For example, if DNAPL is observed at one of the downgradient lateral transect locations, then additional lateral transect locations would be added downgradient of the DNAPL observation to define the "core" of the dissolved phase plume and plume concentrations in the "near source" zone. It should be noted that an observation of DNAPL at a location downgradient of the PDSA may not be onerous for demonstrating natural attenuation because this occurrence would mean that greater degradation rates and/or lower constituent transport rates than those assumed in the GFTER would be required to explain the reduction in dissolved concentrations downgradient of the PDSA's.

2.4.2 Evaluation Data

Samples of DNAPL will be collected from the northern and southern PDSAs for laboratory determination of density, viscosity and interfacial tension to verify that DNAPL properties assumed in the Site conceptual model presented in the GFTER are representative. This information will be used to assess the potential for DNAPL mobility under prevailing and reasonably assumed future non-pumping conditions.

Density, viscosity, and interfacial tension measurements will be measured according to ASTM D1298, ASTM D446, and the du Nouy Ring Method, respectively. Supplemental qualitative information regarding the downgradient limits of the PDSAs will be obtained through visual inspection of soil samples from the direct-push boring locations for the absence or presence of DNAPL. In addition, the results of the groundwater analysis for BTEX and PAH compounds in shallow groundwater downgradient of the PDSAs may also provide useful information for verification of DNAPL immobility and PDSA limits. As indicated previously, DNAPL immobility and the downgradient extent of the PDSA will be verified during the future monitoring program through the installation of "sentry" wells at the estimated downgradient limits of the PDSA's

2.4.3 Sampling Locations and Frequency

A total of four DNAPL samples will be collected to evaluate the DNAPL physical properties. One sample will be collected from each of the four existing DNAPL recovery wells during a one-time sampling event as indicated on Table 1. One well to be sampled (RWN-4) is located within the limits of the northern PDSA. The other DNAPL samples will be collected from recovery wells located in the southern section of the Site: RWS-1, located within the downgradient (i.e., western) portion of the southern PDSA; RWS-2 located along the southern Site boundary in the upgradient portion of the PDSA; and, RWS-5 located along the eastern (upgradient) Site boundary. The locations of the existing DNAPL recovery wells are shown on Figures 5 and 6. The DNAPL samples will be tested in a laboratory to determine the density, viscosity and interfacial tension (with Site groundwater) of the Site DNAPL.

Direct-push soil and groundwater sampling points will be located downgradient of both the northern and southern most PDSAs (Figures 5 and 6). Soil samples will be visually inspected at continuous intervals from ground surface to the top of the intermediate clay/sandy clay confining unit underlying the shallow silty sand unit (Units 2 and 1, respectively, on Figure 7). Groundwater samples will also be collected for laboratory analysis of BTEX and PAH compounds. Visual inspection of the soil samples and evaluation of the groundwater concentration data (with respect to the compound effective solubility) obtained at these locations may also provide supplemental information for evaluation of model boundary conditions with respect to PDSA limits.

2.4.4 Decision Rules

The evaluation criteria for DNAPL density and viscosity correspond to typical values for creosote DNAPL, as presented in the published technical literature, and as referenced in the GFTER.

The typical density range for creosote is from 1.01 to 1.05 grams/cubic centimeter (g/cc), though densities of 1.14 g/cc have been measured in some blends. These data were utilized, in conjunction with Site stratigraphic and operational history information, as part of the GFTER conceptual model, to conclude that the DNAPL has attained a static distribution within the subsurface. Measured densities greater than 1.01 g/cc will therefore be considered to verify the GFTER conceptual model with respect to creosote density and the expected stratigraphic controls on migration. If measured density values are greater or less than the evaluation criteria range of 1.01 to 1.14 g/cc, then the conceptual model will be revised with respect to density.

The GFTER assumes that the viscosity of the DNAPL is similar to typical creosote, which ranges from 10 to 70 centipoise. The GFTER also indicates that viscosities within, or greater than, this range tend to limit the potential for migration. Measured viscosity values for DNAPL that exceed 10 centipoise will be considered consistent with the GFTER conceptual model with respect to migration potential, as it relates to viscosity. If measured viscosity values are less than the evaluation criteria, the conceptual model will be revised with respect to viscosity.

Interfacial tension will be measured and evaluated with respect to site-specific hydraulic gradient and hydraulic conductivity using the relationships shown in Figure 8. This quantitative evaluation will be used to demonstrate the immobility of DNAPL under site-specific conditions. If DNAPL mobility is indicated, then the Site conceptual model will be revised with respect to interfacial tension.

If soil samples collected along the longitudinal transect downgradient of the northern and southern PDSAs are observed to be visually impacted with DNAPL, then the PDSA of interest will be re-delineated in the hydraulically downgradient direction. If DNAPL is observed and the current concentrations of dissolved COI are consistent with those observed in the past, then this situation will be considered to indicate that dissolved-constituents are being attenuated at greater rates than previously indicated. As part of the future monitoring program, DNAPL "sentry wells" may be installed at the inferred downgradient limit of the PDSA's for monitoring to document the immobility of the DNAPL, if necessary.

2.5 Potential Groundwater Usage

2.5.1 Objectives

The accuracy of the current understanding of groundwater use in the vicinity of the Site will be confirmed. Information considered in the GFTER indicates that shallow groundwater is not used within a 1-mile radius of the Site, and that potential future use of shallow groundwater in the vicinity of the Site is extremely unlikely.

2.5.2 Sources of Information

Evaluation of groundwater usage will be based on information acquired using the HGCSD water well database, and by contacting appropriate personnel from the City of Houston and HGCSD. The entire HGCSD water well database will be queried to determine the nearest location of shallow groundwater use in the area downgradient of the Site. This search will serve as a check and an update on previous well inventories. A review of local hydrologic conditions will also be completed to determine the location of the nearest downgradient shallow groundwater discharge point. In addition, the HGCSD will also be asked to provide information on any recent applications for the installation of groundwater extraction wells within the area between the Site and the nearest shallow groundwater user or shallow groundwater discharge area. Also, the HGCSD will be asked to provide information regarding any planned future restrictions on groundwater use in the area.

City of Houston personnel will be contacted to determine the public water supply source for the area surrounding the Site. Information regarding the current cost and availability of water supplied through the municipal system will also be requested. This information will be used to compare the construction and operation costs of using groundwater versus the cost of using water from the local public supply. Also, information regarding long-term water use projections will be requested from the local supplier. This information will serve to indicate the potential for future installation of groundwater extraction wells within the vicinity of the Site.

2.5.3 Decision Rules

The current understanding of groundwater usage in the vicinity of the Site will serve as the evaluation criterion. If the information reviewed affirms that the potential for current and future use of shallow groundwater in the vicinity of the Site is unlikely, then the GFTER Site conceptual model will be considered supported with respect to groundwater use. The hypothetical future groundwater exposure points assumed in the fate and transport evaluation represent the nearest possible downgradient locations to the PDSAs where groundwater extraction could occur in the future. This is because on-Site property owners are prohibited from installing groundwater production wells on their properties by virtue of their respective Consent Orders with the United States and corresponding settlement/access agreements with Beazer, and active rail lines, public roads and/or active industrial facilities occupy the areas between the PDSAs and the hypothetical future groundwater withdrawal wells. Therefore, modifications to the assumed locations of future groundwater withdrawals will not be necessary, even if the groundwater usage information indicates that current or future use of shallow groundwater in the downgradient vicinity of the Site is possible. However, the Site conceptual model will be updated to reflect these findings, if appropriate.

3.0 GROUNDWATER SAMPLING TO EVALUATE NATURAL ATTENUATION OF DISSOLVED-PHASE CONSTITUENTS

Additional site-specific data pertaining to dissolved constituent distribution and indicators of intrinsic biodegradation will be collected. The overall objectives of this component of the work is to verify that biodegradation is occurring in groundwater and to evaluate whether the distribution of dissolved COI and indicators of intrinsic biodegradation are consistent with natural attenuation. Groundwater and soil samples will be collected from strategic locations on- and off-Site and compared with existing data, where appropriate, to address the following specific objectives:

- To acquire data within the "cores" (zones of relatively high concentration) of the dissolved phase plumes for evaluation with respect to GFTER conclusions (Section 3.1);
- To determine whether intrinsic biodegradation indicators are consistent with natural attenuation (Section 3.2); and,
- To assess the current downgradient extent of COIs and its effect on GFTER conclusions (Section 3.3).

It is expected that data collected to meet these objectives will support the overall conclusion of the GFTER: that monitored natural attenuation will prevent dissolved-phase COI migration from on-Site source areas to downgradient locations of hypothetical future groundwater extraction wells. In conjunction with the implementation of the Work Plan, Beazer will conduct a comprehensive review of existing information as it pertains to the delineation of the source areas, potential groundwater constituent migration pathways and extent of dissolved constituents in shallow groundwater. The findings of this review, as well as evaluation of the real-time data acquired through implementation of the Work Plan, will serve as the basis for development of supplemental characterization activities to be completed, if necessary, in conjunction with the investigation proposed in the Work Plan. The purpose of the supplemental characterization activities, if necessary, will be to assess if any other dissolved phase plumes (other than the two plumes to be addressed under the Work Plan) exist which may potentially migrate from the Site to the locations of hypothetical potential future groundwater receptors.

3.1 Plume Core Location (BTEX and PAH)

3.1.1 Objectives

A valid comparison of COI concentrations to GFTER modeling results, for the purpose of verifying natural attenuation, requires that the groundwater samples from downgradient of the source areas be representative of maximum concentrations, which will occur near the core of the plume. If concentration data collected from the periphery of the plume are utilized for comparison to model results, then there may be potential to overestimate the effects of natural attenuation. Consequently, the focus of some of the sampling will be to ensure that downgradient concentration data utilized for comparison to modeling results are representative of maximum concentrations at given distances from the source so that the effects of natural attenuation are not overestimated.

3.1.2 Evaluation Data

The assessment of the plume core location will be based on the distribution of BTEX and PAHs in groundwater. The groundwater sampling and analysis program for BTEX and PAHs is summarized in Table 2. These analyses will be conducted by a subcontracted laboratory in accordance with the analytical methods specified in Table 3.

The selected laboratory will meet the Consent Decree requirements and will have experience with the analyses requested. Local laboratories will be preferred due to shorter sample holding times for some of the proposed analyses.

3.1.3 Sampling Locations and Frequency

Groundwater samples for BTEX and PAH analyses will be collected along transects to be located transverse to groundwater flow direction and directly downgradient of the northern and southern PDSAs, as indicated in Figures 5 and 6, respectively. As shown, a minimum of seven sampling locations in each area are proposed to define the plume core in the northern and southern areas. The sampling points will be located as follows:

- The first sampling point in each transect will be located on the assumed axis of each plume, at the approximate downgradient distance shown on the figures.
- The location of the plume axes will be estimated to be directly downgradient of the center of the PDSAs, in the direction of groundwater flow.
- Groundwater flow direction will be determined by monitoring existing wells prior to the transect boring program.
- At least three additional sampling points will be located on each side of the initial point, in the direction transverse to groundwater flow (minimum of seven sampling points in the transect).
- The additional sampling points will be spaced equidistant (approximately 40 feet apart).
- Additional sampling points will be added on either side of the initial point, until the edges of the core of the plume are defined.
- Adjustment of the proposed sampling locations may be required due to access considerations.

Application of the above criteria is likely to result in adjustment and augmentation of the locations shown on Figures 5 and 6.

The samples will be collected on a one-time basis using direct-push methods with temporary well screens. Samples will be collected from the shallow, saturated, silty sand unit (i.e., the hydraulic zone of interest) as confirmed by continuous stratigraphic logging starting at a depth of 2 ft-bgs. Groundwater samples will be collected at two foot vertical intervals from the water table to the bottom of the silty sand unit. Field screening using a mobile GC will be performed on all groundwater samples and the interval of greatest benzene and/or naphthalene concentrations at each location along the transect will be submitted to the subcontracted analytical laboratory for BTEX and PAH analysis.

3.1.4 Decision Rules

Data from all locations in the transect will be used to evaluate the horizontal and vertical distribution of COIs in the shallow zone for transverse (i.e., two dimensional) delineation of the plume cores. These data will be used to evaluate the location of the plume core in three dimensions by defining the core of the plume as the zone that extends downgradient from the source, through all transect points that contain concentrations greater than 50% of the maximum concentration detected along the transect. It is possible that this definition will lead to identification of multiple plume cores within the transect, separated by zones of lower concentration. The monitoring locations used for comparison to the GFTER fate and transport model (i.e., MW-01 and MW-08) will be compared to the plume core locations. If they are located within the core of the plume, as defined above, then data from these locations will be considered sufficiently representative of maximum plume concentrations, and supportive of the model conclusions. If the monitoring locations are outside the cores of the plumes, then they will be considered unrepresentative of maximum plume concentration at the given distance from the source. Implications with respect to the model conclusions will be considered in conjunction with the other data and information that will be obtained during this investigation.

3.2 Intrinsic Biodegradation

3.2.1 Objectives

Biodegradation is one of the natural attenuation processes accounted for in the GFTER fate and transport model. The model allowed for relatively slow rates of dissolved constituent biodegradation, on the basis that most creosote compounds are known to be biodegradable to some degree. In keeping with the inclusion of biodegradation in the GFTER transport model, groundwater and soil sampling will be conducted in order to:

- Determine whether differences in biodegradation indicator parameters from background locations and locations within the dissolved phase plume are consistent with biodegradation;
- Evaluate whether conditions in the vicinity of the plume are conducive to biodegradation of dissolved constituents; and
- Evaluate whether biodegradation of COIs is leading to accumulation of substantial quantities of organic byproducts or metabolites in groundwater.

3.2.2 Evaluation Data

Groundwater samples will be analyzed for electron acceptors, inorganic biodegradation by-products, microbial nutrients, general chemistry parameters, and TOC. Soil samples will be analyzed for specialized microbial indicators to evaluate the following:

- The presence of active BTEX- and PAH-degrading microbes;
- The degree of microbial activity;
- The availability and utilization of microbial nutrients and electron acceptors; and,
- Microbial environmental conditions.

The selection of data to demonstrate intrinsic biodegradation is based in part on the following references:

- *Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater*[21]

- *BIOSCREEN Natural Attenuation Decision Support System User's Manual*[22]

- *Migration and Natural Fate of a Coal Tar Creosote Plume*[23]

The specific sampling and analytical program is summarized in Table 1 and analytical methods are summarized in Table 2. Groundwater sample collection, preservation and analysis will be conducted according to methods described in the SOPs (Appendix A). In addition, low flow

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21 Wiedemier, T., Wilson, J.T., Kampbell, D.H., Miller, R.N., Hansen, J.E., 1995, *Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater*, Brooks AFB, San Antonio, Texas, Air Force Center for Environmental Excellence Technology Transfer Division, v.1, 2.

22 Newell, C.J., McLeod, R.K., Gonzales, J.R., and Wilson, J.T., August 1996, *BIOSCREEN Natural Attenuation Decision Support System User's Manual*, v.1.3, EPA/600/R-96/087.

23 King, M.W.G., 1997, Migration and Natural Fate of a Coal Tar Creosote Plume, Ph.D. Thesis, University of Waterloo, Waterloo, Ontario, Canada.

purging and sampling techniques will be employed for the sampling proposed in this section. A flow-through cell will be utilized in conjunction with sample collection for field parameter measurements.

The observation of diminished electron acceptor concentrations (dissolved oxygen, nitrate, sulfate) and the accumulation of biodegradation by-products (ferrous iron, carbon dioxide, methane) in groundwater zones containing organic constituents, relative to upgradient or background conditions, is an indication that constituent mass is undergoing biodegradation. The presence of microbial nutrients will be evaluated as an indication of whether subsurface conditions are favorably supporting microbial activity. Phosphorous, in particular, is an important nutrient for BTEX- and PAH-degrading bacteria. General chemistry parameters (chloride, alkalinity, pH, biochemical oxygen demand, chemical oxygen demand) will be utilized to define the chemical conditions of the aquifer. These data will provide additional information pertaining to whether groundwater environmental conditions are amenable to microbial activity.

TOC sampling and analysis will be performed to provide an indication of whether substantial quantities of organic byproducts or metabolites may be accumulating in groundwater downgradient of the source. It is probable that such intermediates are formed through the biodegradation of parent compounds. However, these intermediates are generally expected to be short-lived and highly biodegradable. A wide and unpredictable range of intermediates may be formed during biodegradation, depending on the parent compound, the governing redox condition and other environmental factors. Consequently, TOC will be used as a "surrogate" parameter to evaluate the quantity of plume-derived organic compounds that may be present but not detectable through analysis of BTEX and PAHs.

Soils samples will be analyzed for phospholipid fatty acids and PAH gene probes. Phospholipid fatty acids represent a component of the microbial structure, and can be used as an indicator of microbial numbers and growth. PAH gene probes test for a specific genes associated with the microbial ability to degrade PAHs. These analyses will be conducted by Microbial Insights in Knoxville, Tennessee.

3.2.3 Sampling Locations and Frequency

One round of groundwater intrinsic biodegradation indicator data will be collected from locations shown on Figure 9 and summarized in Table 4. Groundwater sampling points were selected to be representative of the following four types of locations:

- *background* - expected to indicate relatively oxidizing conditions due to lack of COIs;
- *within the source* - expected to show highly reducing conditions due to abundant; biodegradable COIs and corresponding depletion of electron acceptors;
- *within the plume / near-source* - expected to show moderate COI concentrations and relatively reducing conditions; may be somewhat less reducing than the source location, due to re-introduction of electron acceptors along the groundwater flow path; and,
- *within the plume / far-source* - expected to show relatively low or non-detectable COI concentrations and redox conditions that are between background and near-source levels, due to further re-introduction of electron acceptors.

At each location, groundwater samples will also be collected for analysis of BTEX and PAH compounds to evaluate whether groundwater chemistry is representative of the target zones. Single soil samples for analysis of microbial parameters will be collected from direct-push soil borings to be located adjacent to the upgradient and near-source groundwater sampling locations, as indicated in Table 4. The intrinsic biodegradation indicator data may be collected at alternate locations due to access considerations or the results of the field screening using direct push sampling and a mobile GC.

3.2.4 Decision Rules

Concentrations of biodegradation indicators at background locations and within the dissolved-phase plume will be evaluated to determine whether parameter distributions and concentration trends the hypothesis that intrinsic biodegradation is occurring. In general, a qualitative comparison of means will be used to compare sample groups from the four types of locations. The following general trends will be considered to be consistent with a contribution of intrinsic biodegradation:

- Decrease in electron acceptors, Eh and nutrients from background locations to source zone locations;
- Increase in electron acceptors, Eh and nutrients from the source zone, to the near-source zone, to the far-source zone;
- Increase in dissolved iron, dissolved manganese, methane, and TOC from background to source zone locations.
- Decrease in dissolved iron, dissolved manganese, methane and TOC from the source zone, to the near-source zone, to the far-source zone;
- Increase in microbial biomass, and PAH-degrading genes from background locations to plume zone locations.

Biodegradation of organic compounds is complex and will depend on site-specific geochemistry, for example, availability of various electron acceptors. Consequently, lack of expected change in any of these parameters will be considered inconclusive with respect to natural attenuation. Data related to intrinsic biodegradation indicators will be evaluated in conjunction with other data generated pursuant to this investigation to complete an assessment of the effectiveness of natural attenuation.

3.3 Downgradient Extent of COI

3.3.1 Objectives

The objective of the scope of work described in this section is to acquire additional characterization of the longitudinal distribution of COI in groundwater, along the approximate plume center lines. Certain of these data will be compared to past COI concentrations to evaluate whether concentrations at these points are increasing, decreasing or stable. Center line profiles will be compared with the GFTER simulations, for additional evaluation of plume status: advancing receding or stable.

3.3.2 Evaluation Data

Groundwater samples will be collected for BTEX and PAHs, which are the primary dissolved organic components of the shallow groundwater plume. Assuming source concentrations of dissolved COIs are constant, these data can be compared to previous data and the GFTER modeling results to evaluate whether the dissolved-phase groundwater plume is receding, in a steady-state configuration, or if the potential for future plume migration exists. The sampling and analytical program is summarized in Table 2 and analytical methods are presented in Table 3.

3.3.3 Sampling Locations and Frequency

Section 3.1 describes a groundwater sampling program along direct-push transects located downgradient of the northern and southern PDSAs, and oriented transverse to the direction of groundwater flow. COI concentration data from these transects will be used to estimate the transverse and longitudinal locations of the plume cores (Section 3.1.4). This information will be used to locate sampling points longitudinally along the estimated plume cores. Note that the longitudinal location of the plume core will be considered indicative of the plume center line.

Two sampling points will be located between each of the transverse transects and their respective PDSAs. An additional groundwater sampling point (i.e., proposed off-site monitoring well) will be located downgradient of the northern transect. For the southern area, an additional point will only be installed downgradient of the transect if the transect data indicate that neither MW-08 or MW-17 are located along the plume core. These additional plume center line sampling locations will be in the form of temporary direct-push points, with the exception of the downgradient locations in both areas, which will be completed as a permanent monitor wells. Construction specifications of these proposed wells are shown in Figure 10 and will resemble that of existing MW-01, which is known to screen the entire thickness of the silty sand unit.

Groundwater samples will also be collected from selected existing monitoring wells in both the northern (MW-01) and southern areas (MW-08 and Mobil well MW-17). Sampling locations for the northern and southern areas are indicated on Figures 5 and 6, respectively, and summarized in

Table 2. One groundwater sample will be collected for BTEX and PAH analysis from each of the above noted sampling locations.

3.3.4 Decision Rules

The objective of the decision rules pertaining to comparison of current and past concentration data from selected monitoring points (MW-01, MW-08 and Mobil well MW-17) is to evaluate for long term trends in groundwater concentrations (i.e., increasing, decreasing or stable). At the same time, the decision rule must allow for the following limitations:

- previous data available from these wells is limited in terms of the quantity of existing data;
- variability associated with sampling and analytical techniques; and
- short term processes that affect concentration, such as seasonal effects or hydrologic events.

Given these limitations, the decision rule will rely on an overall assessment of data trends, rather than statistical methods. Details of the decision rules are as follows:

- If recent data from existing monitoring wells are less than the maximum concentration observed at a given monitoring point in the past, then the data will be considered consistent with a stable plume at the given location and the natural attenuation conclusions in the GFTER.
- If recent concentration is greater than the maximum observed in the past, then the analytical variability of the new data will be compared with that of the previous data using the analytical quality control criteria stipulated for the particular COI and corresponding analytical method in EPA SW-846. If the ranges of error associated with these two measurements do not overlap, then the data will be considered inconsistent with a stable plume at the given location and the natural attenuation conclusions in the GFTER.

In any case, the comparison of time series data will be considered preliminary due to the limitations mentioned previously; it would be improved by incorporation of subsequent data that may be collected through a future monitored natural attenuation groundwater sampling and analysis program, should one be implemented at the site.

The decision rule pertaining to plume center line data will be based on comparison of center line concentrations (within the core of the plume) with the GFTER modeling results. If the actual plume profile shows concentrations that are comparable to, or lower than, the modeling results, then the model will be considered protective. If the actual plume profile shows concentrations that are greater than the modeling predictions, then the model will be re-run with updated, site-specific fate and transport parameters. Results of the updated model will be evaluated to determine whether the overall GFTER conclusion, that natural attenuation prevents migration of COIs to hypothetical future downgradient exposure points, is still supported.

Section 4.0

4.0 REPORTING

Following implementation of the scope of work, acquired data and information will be evaluated within the decision rule process, and a report will be prepared and submitted to EPA. The report text, tabular information and graphical presentations will be provided to EPA in electronic formats. The report text will be provided in WordPerfect© Version 8.0, spreadsheets in Microsoft® Excel Version 5.0 and drawings as AutoCAD Version 13 .DWG files.

This report will include the following items:

- A description of the sampling and information acquisition program;
- A presentation and summary of data;
- An evaluation of changes of electron acceptor concentrations and changes in microbial indicators to describe the biological processes acting to degrade the COIs;
- A data evaluation with respect to model input parameter assumptions;
- A proposal for a change to the groundwater remedy, if appropriate;
- A recommendation for selection of monitored natural attenuation as the groundwater remedial alternative for the shallow aquifer at the Site, if appropriate and,
- An outline for a groundwater monitoring plan to provide time-series and, if necessary, additional spatial dissolved COI concentration data to verify effective natural attenuation of COI in the shallow groundwater zone.

The report will provide conclusions as to whether a monitored natural attenuation alternative is appropriate, as well as to the degree the GFTER characterizes the Site and its potential for natural attenuation. Multiple lines of evidence will be compiled in the process of arriving at any conclusions about the Site and/or the GFTER. These conclusions will be based on the entirety of the data collected as part of this Work Plan. Individual results, differing from those estimated in the GFTER, are not anticipated to be significant enough to disqualify the GFTER.

The report narrative will be supplemented by the following anticipated tabular and graphical information, as necessary and applicable:

Tabular Information

- Field screening (mobile GC) data;
- Listing of samples submitted for laboratory analysis and analytical parameters;
- DNAPL properties;
- Aquifer matrix TOC results;
- Aquifer matrix physical properties;
- Potentiometric surface elevation data;
- Groundwater field parameter measurements;
- All groundwater analytical results; and,
- Intrinsic biodegradation indicator data.

Graphical Presentation

- Facility location map;
- Site plan with significant Site features;
- Maps indicating sample locations;
- Maps depicting the current distribution of COI in groundwater;
- A hydrogeologic map (a lithologic cross-section with water table elevations) will be included as an aid to understanding the direction of groundwater flow and limits of the PDSA's with respect to the various lithologic zones in both the northern and southern areas;
- A map indicating the locations of off-Site groundwater wells, if any;
- Bar charts illustrating biodegradation indicator parameter values at background locations, within the PDSAs and locations within the plumes; and,
- Figures and/or graphs comparing the current COI concentrations to GFTER modeling predictions.

5.0 SCHEDULE

The critical path for the project schedule is presented in Figure 11. Implementation of this scope of work requires access to off-site properties. Beazer will need to secure permission to access these properties prior to initiation of field activities. Beazer will initiate the process of securing off-site access upon submittal of this revised Work Plan. The start date for the schedule presented in Figure 11 will be the date that access agreements have been secured with all necessary off-site property owners.

It is anticipated that field investigative activities for this project can be initiated within 14 days following receipt of all necessary access agreements. The mobilization schedule will be dependent upon weather conditions and subcontractor availability. The schedule for sample collection activities will be coordinated with Beazer and EPA. The EPA will be notified at least seven days prior to initiation of sampling activities.

The project schedule does not include any time for possible delays which could result due to factors beyond the reasonable control of Beazer and/or their subcontractors. These events may include, but are not necessarily limited to, delays for severe weather or an increase in the scope of work, and securing access agreements needed for additional work, if any. In addition, this Work Plan provides for focused data collection based on the Beazer and EPA project team's interpretation of preliminary field data. This approach may result in some variability in the schedule.

In the event that Beazer becomes aware of a potential delay, information regarding the cause and expected duration of the delay will be promptly communicated to EPA Region VI. The project schedule will be modified accordingly accounting for the actual time of delay plus reasonable additional time to allow for resumption of work, if appropriate. A revised schedule will then be provided to EPA.

TABLES

KEY

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TABLE 1

CONSTITUENTS OF INTEREST IN SHALLOW GROUNDWATER
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON,TEXAS
BEAZER EAST, INC.

Volatile Organic Compounds
Benzene
Ethylbenzene
Toluene
Xylenes
Polynuclear Aromatic Hydrocarbon Compounds
Acenaphthene
Anthracene
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(g,h,I)perylene
Chrysene
Fluoranthene
Fluorene
Naphthalene
Phenanthrene
Pyrene

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TABLE 2
PROPOSED SAMPLING PROGRAM SUMMARY
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS
BEAZER EAST, INC.

SAMPLE MEDIA	QUANTITY	COLLECTION METHOD	PARAMETERS	LOCATIONS	WORK PLAN SECTION AND FIGURE REFERENCE
DNAPL	1 North 1 South	Peristaltic Pump and/or Stainless Steel Bailer	Density Viscosity Interfacial Tension	RWN-4(n), RWS-1(s) RWS-2(s), RWS-5(s)	Section 2.4 Figures 5 and 6
Aquifer Soil Matrix	4 North 4 South	Direct-Push	TOC Grain Size Bulk Density Particle Density	Outermost borings on each Transverse Transect(n,s) Top and bottom of silty sand unit in each boring	Section 2.2 Section 2.3 Figures 5 and 6
Aquifer Soil Matrix	4 North 3 South	Direct-Push	Phospholipid Fatty Acids PAH Gene Probes	***Adjacent to*** MW-03(n), OW-07(n), MW-07(s) Two Longitudinal Tansects (n,s)	Section 3.2 Figure 9
Groundwater	11 North 11 South	Direct-push - temporary well screen, and pump, bailer, or siphon tube. Monitoring Wells - Bailer and/or Peristaltic Pump	BTEX PAH Field Parameters	9 Direct Push Points (n,s) New Off-Site Well(n) MW-01(n), MW-17(Mobil)(s) MW-08(s)	Sections 3.1 and 3.3 Figures 5 and 6
Groundwater	3 North 2 South	Bailer and/or Peristaltic Pump	BTEX PAH Field Parameters	MW-03(n), OW-07(n), OW-02(n) MW-07(s), OW-10(s)	Section 3.2 Figure 9
Groundwater	6 North 6 South	Bailer and/or Peristaltic Pump	Chloride Nitrate Sulfate Iron (II) Methane Carbon Dioxide Alkalinity Phosphorous TOC Field Parameters	MW-03(n), OW-07(n),OW-02(n), Two Longitudinal Transect Borings (n) New Off-Site Well (n) MW-07(s), OW-10(s) Two Longitudinal Transect Borings (s) MW-17 (Mobil)(s), MW-08(s)	Section 3.2 Figure 9

Notes: The designations (n) and (s) represent northern and southern areas, respectively.
Listed sample quantities represent minimum requirements; additional samples may be collected by direct-push.
Sample locations are preliminary based on the current understanding of Site conditions.
See Table 3 for list of Groundwater Field Parameters

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TABLE 3

GROUNDWATER, SOIL AND DNAPL PARAMETERS AND ANALYTICAL METHODS
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS
BEAZER EAST, INC.

PARAMETERS	ANALYTICAL METHODS
Groundwater Field Parameters	
Temperature	Thermometer
pH	pH Probe
Specific Conductivity	S.C. Probe
Eh/ORP	Eh Probe
Dissolved Oxygen	Chemetrics Ampoules*
Laboratory Parameters	
Groundwater	
BTEX	EPA 8020
PAHs	EPA 8270
TOC	EPA 415.1
Chloride	EPA 325.2/325.3
Nitrate	EPA 352.1/353.1
Sulfate	EPA 375.4
Iron (II)	HACH DR700/SM 3500
Methane	RSK-175/GC-FID
Carbon Dioxide	RSK-175
Alkalinity	EPA 310.1/310.2
Phosphorous	EPA 365.1/365.2
Soil	
TOC	EPA 9060
Grain Size	ASTM D422
Bulk Density	ASTM D2937
Particle Specific Gravity	ASTM D854
Phospholipid Fatty Acids	Custom Method#
PAH Gene Probes	Custom Method#
DNAPL	
Density	ASTM - D1298
Viscosity	ASTM - D446
Interfacial Tension	du Nuoy Ring Methyod

* Chemetrics Laboratories dissolved oxygen ampoules.

Microbial Insights Laboratories custom microbial analyses.

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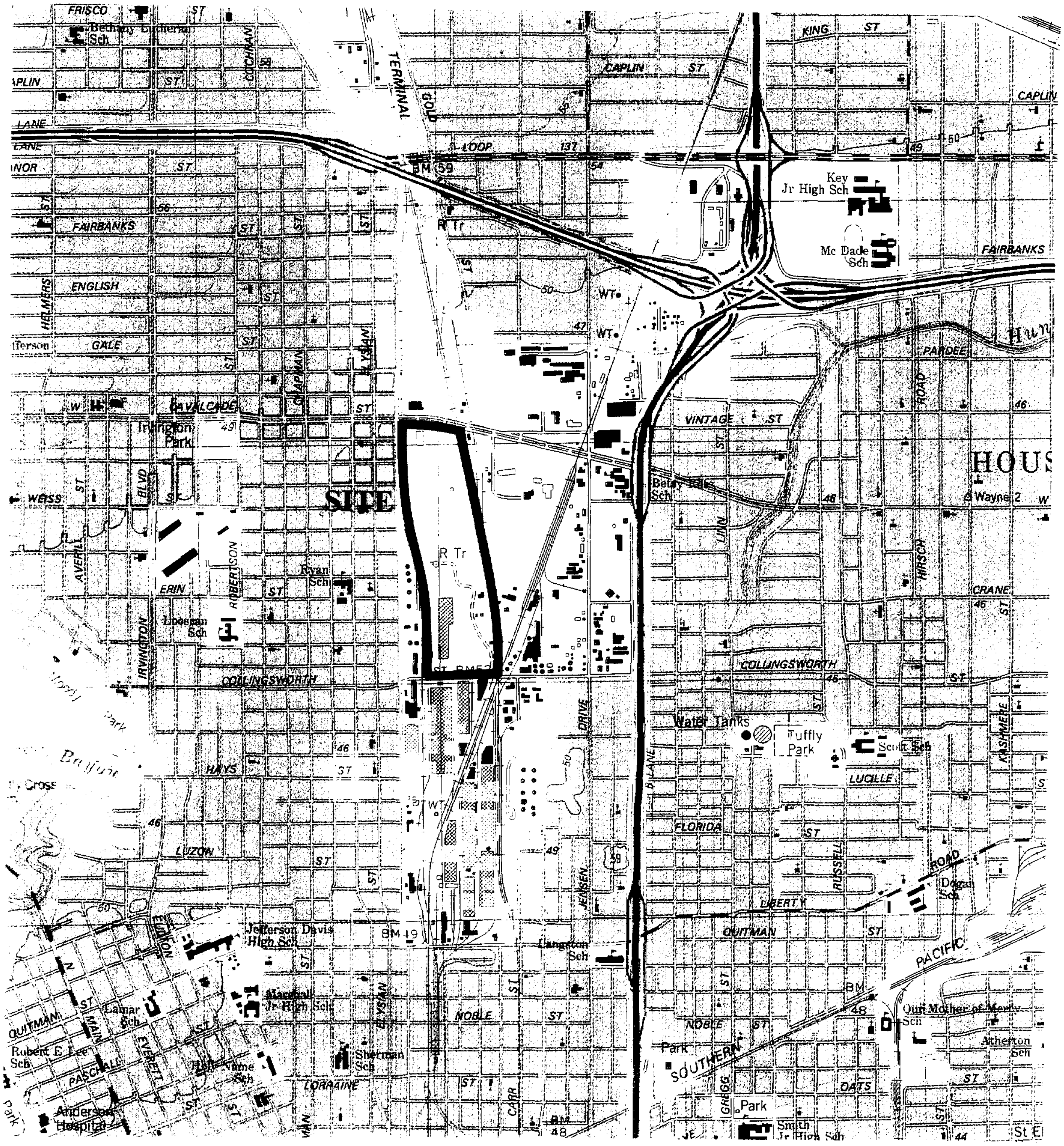
TABLE 4
SUMMARY OF INTRINSIC BIODEGRADATION
SAMPLING LOCATIONS FOR GROUNDWATER AND SOIL
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS
BEAZER EAST, INC.

Location Type	Northern Area	Southern Area
Upgradient or Background	**Groundwater**: MW-03, OW-07 **Soil:** adjacent to MW-03, OW-07	**Groundwater**: MW-07 **Soil:** adjacent to MW-07
Source	**Groundwater:** OW-2	**Groundwater:** OW-10
Plume / Near-Source	**Groundwater**: Two Longitudinal Transect Locations **Soil:** Two Longitudinal Transect Locations	**Groundwater**: Two Longitudinal Transect Locations **Soil:** Two Longitudinal Transect Locations
Plume / Far-Source	**Groundwater:** Proposed Off-Site Monitoring Well (MW-24)	**Groundwater:** MW-17, MW-08

Figures

FIGURES

KEY



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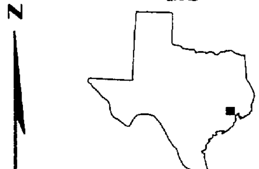

QUADRANGLE LOCATION

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

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CHKD:	JRH	DATE:	09/04/96
APPD:	JSZ	DATE:	09/04/96
SCALE:	1" = 2000'		

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SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

REFERENCE: USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE OF SETTEGAST, TEXAS

KEY ENVIRONMENTAL, INC.

ISSUE DATE:

ROSSLYN FARMS INDUSTRIAL PARK
1200 ARCH ST., SUITE 200
CARNEGIE, PA 15106

SITE LOCATION MAP

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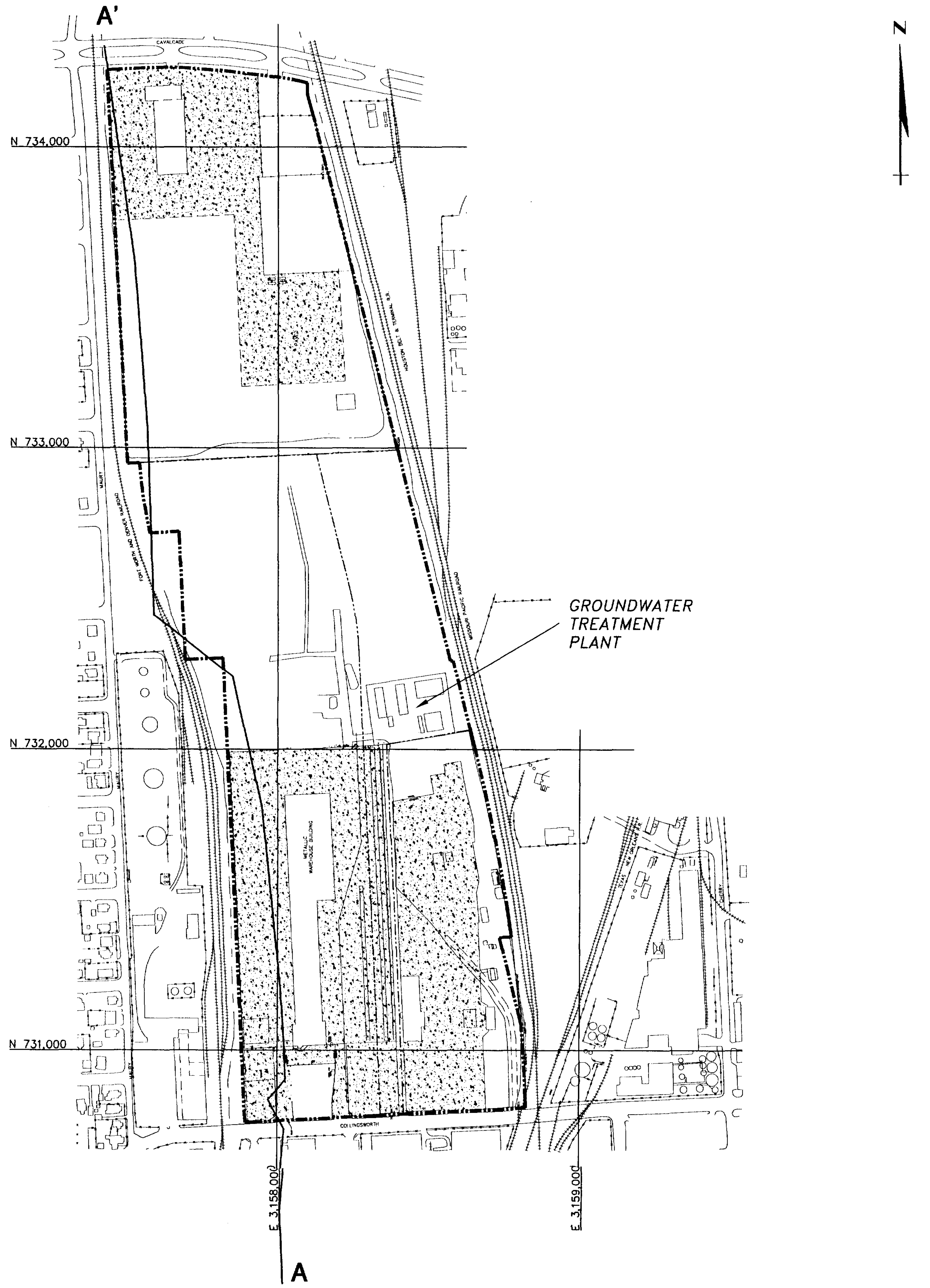
FIGURE 1

EDITED BY:	DATE:	TIME:	EDITING TIME:	DRAWING NAME: C:\CAVALCAD\97366\FIG-02.DWG



LEGEND:

SOUTH CAVALCADE SITE BOUNDARY

PROPERTY BOUNDARIES

AREAS COVERED WITH ASPHALT OR CONCRETE

A A' CROSS SECTION LOCATION

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

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SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

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SITE PLAN

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97366
FIGURE 2

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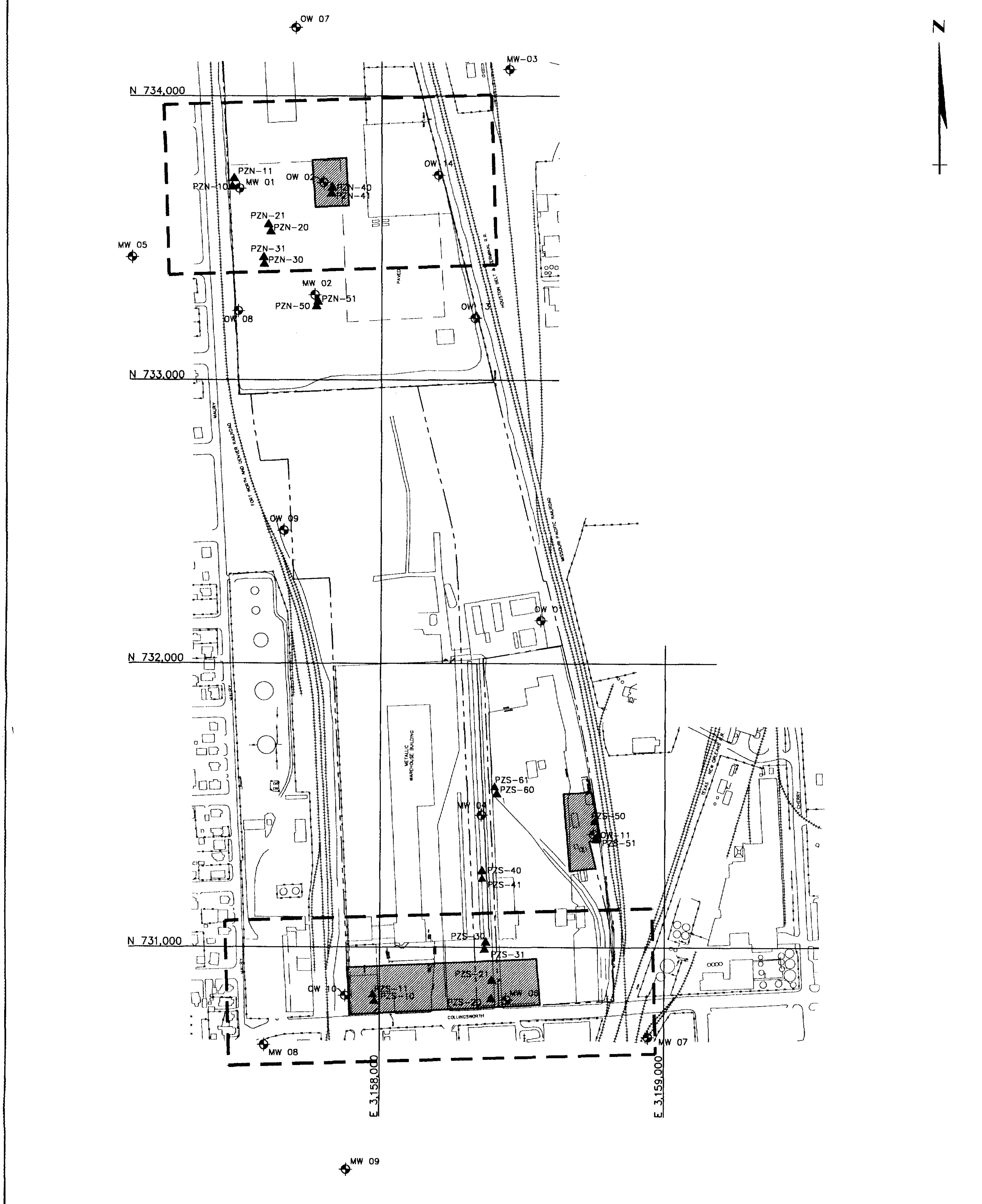

LEGEND:

PREVIOUSLY INSTALLED WELL	POTENTIAL DNAPL SOURCE AREA
PIEZOMETER LOCATION	AREA DESIGNATED FOR HYDRAULIC GRADIENT AND GROUNDWATER FLOW DIRECTION DETERMINATION

0 300 600 FEET

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

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HOUSTON, TEXAS

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AREAS FOR VERIFICATION OF GROUNDWATER FLOW DIRECTION AND HYDRAULIC GRADIENT

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FIGURE 3

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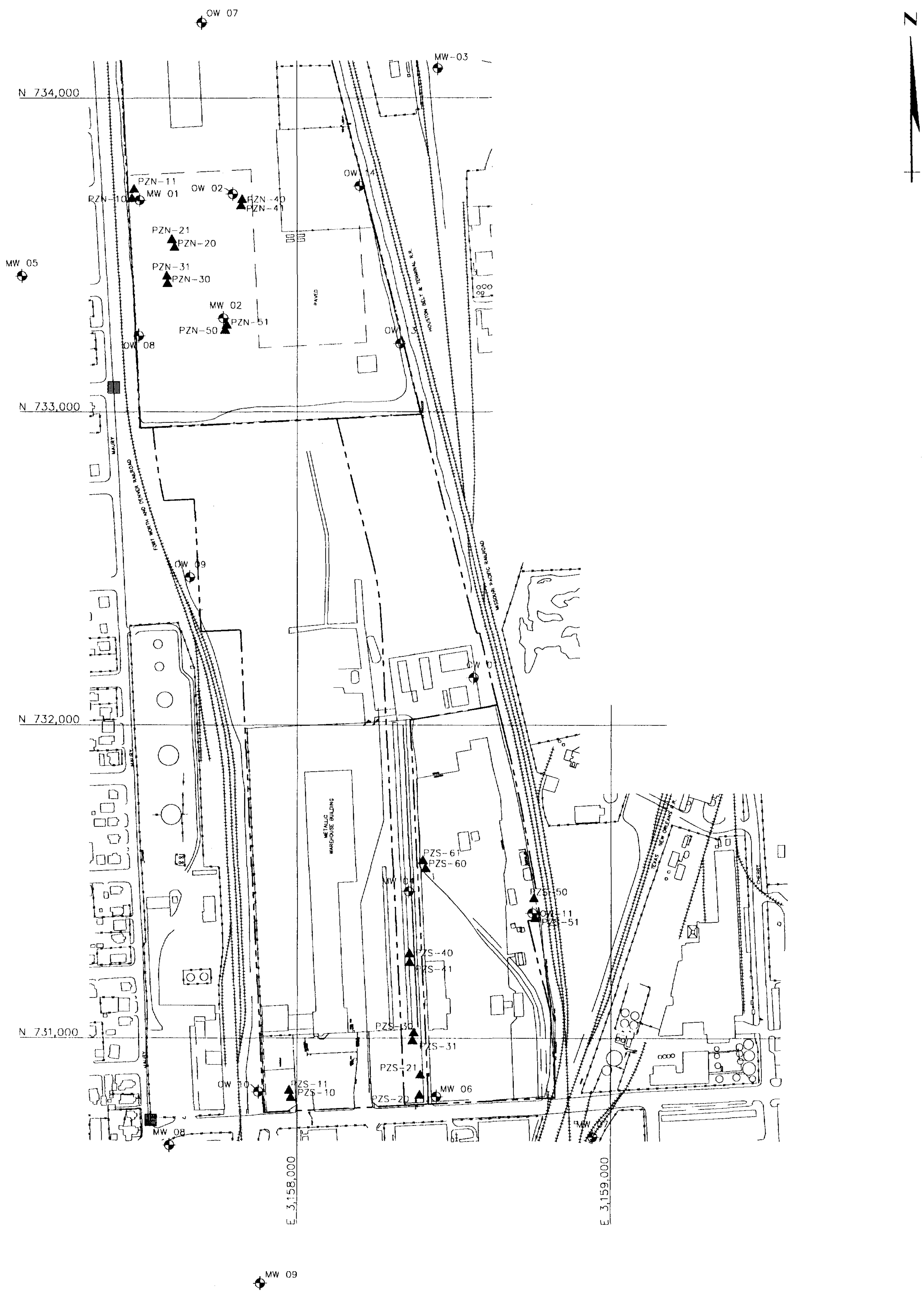

LEGEND:

PREVIOUSLY INSTALLED WELL

PIEZOMETER LOCATION

0 300 600 FEET

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

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CHKD: JRH	DATE: 11/05/97
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PROPOSED SHALLOW AQUIFER POTENTIOMETRIC SURFACE MEASUREMENT LOCATIONS

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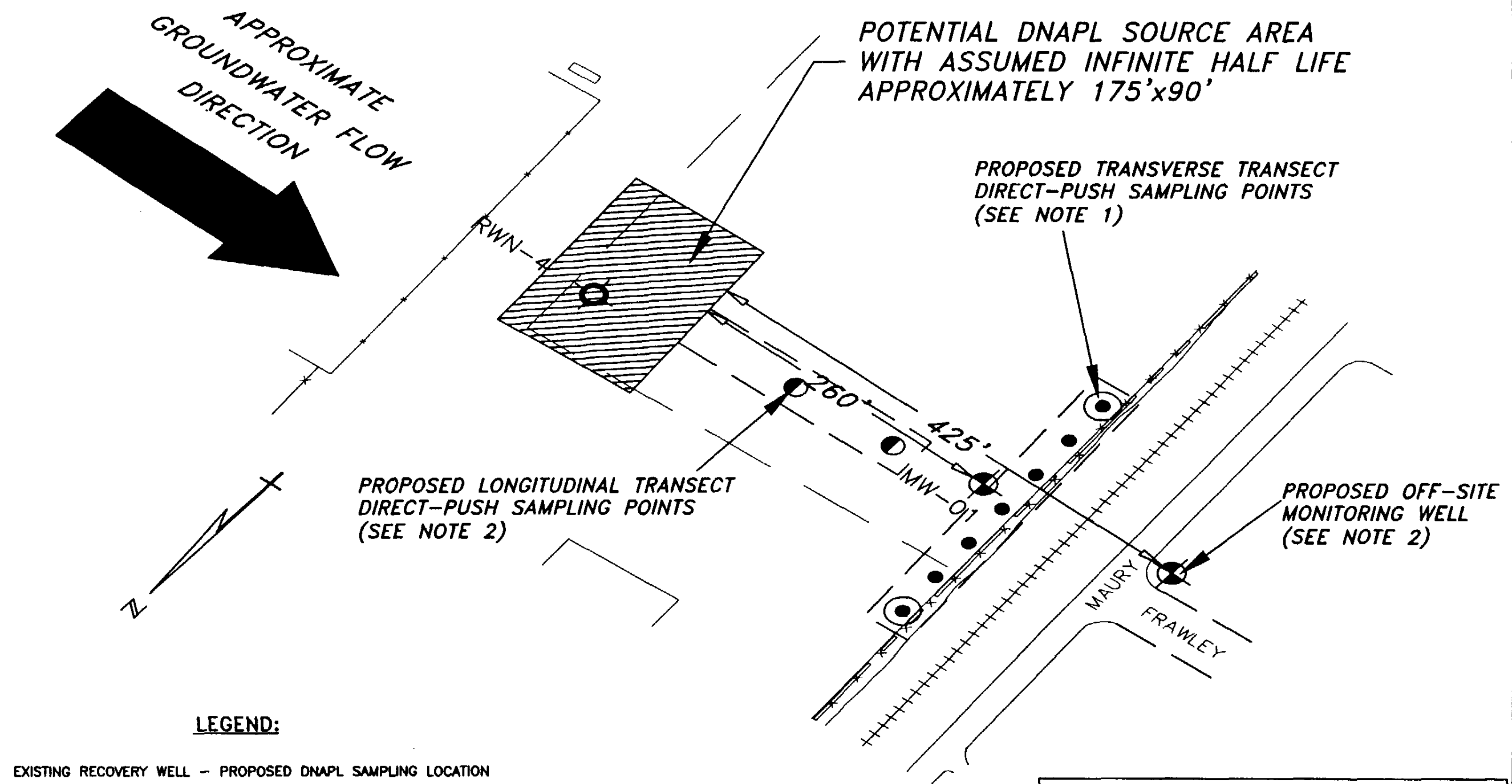
FIGURE 4



LEGEND:

- EXISTING RECOVERY WELL – PROPOSED DNAPL SAMPLING LOCATION
- MONITORING WELL LOCATION – PROPOSED GROUNDWATER BTEX AND PAH ANALYSIS
- PROPOSED DIRECT-PUSH GROUNDWATER SAMPLING LOCATION
- PROPOSED DIRECT-PUSH SOIL SAMPLING LOCATION FOR TOC
- PROPOSED DIRECT-PUSH SOIL SAMPLING LOCATION FOR MICROBIAL INDICATORS

NOTES: 1) EXACT LOCATIONS OF PROPOSED DIRECT-PUSH SAMPLING POINTS AND PROPOSED OFF-SITE MONITORING WELLS WILL BE DETERMINED FOLLOWING EVALUATION OF ACCESSIBILITY AND THE VERIFICATION OF CURRENT GROUNDWATER FLOW DIRECTION.
2) LONGITUDINAL TRANSECT LOCATIONS AND PROPOSED OFF SITE MONITORING WELL LOCATION TO BE WITHIN PLUME CORE AS DETERMINED FROM TRANSVERSE TRANSECT DATA.

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SOUTH CAVALCADE SUPERFUND SITE
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HOUSTON, TEXAS

NORTHERN AREA PLUME AND AQUIFER CHARACTERIZATION POINTS

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98567
FIGURE 5

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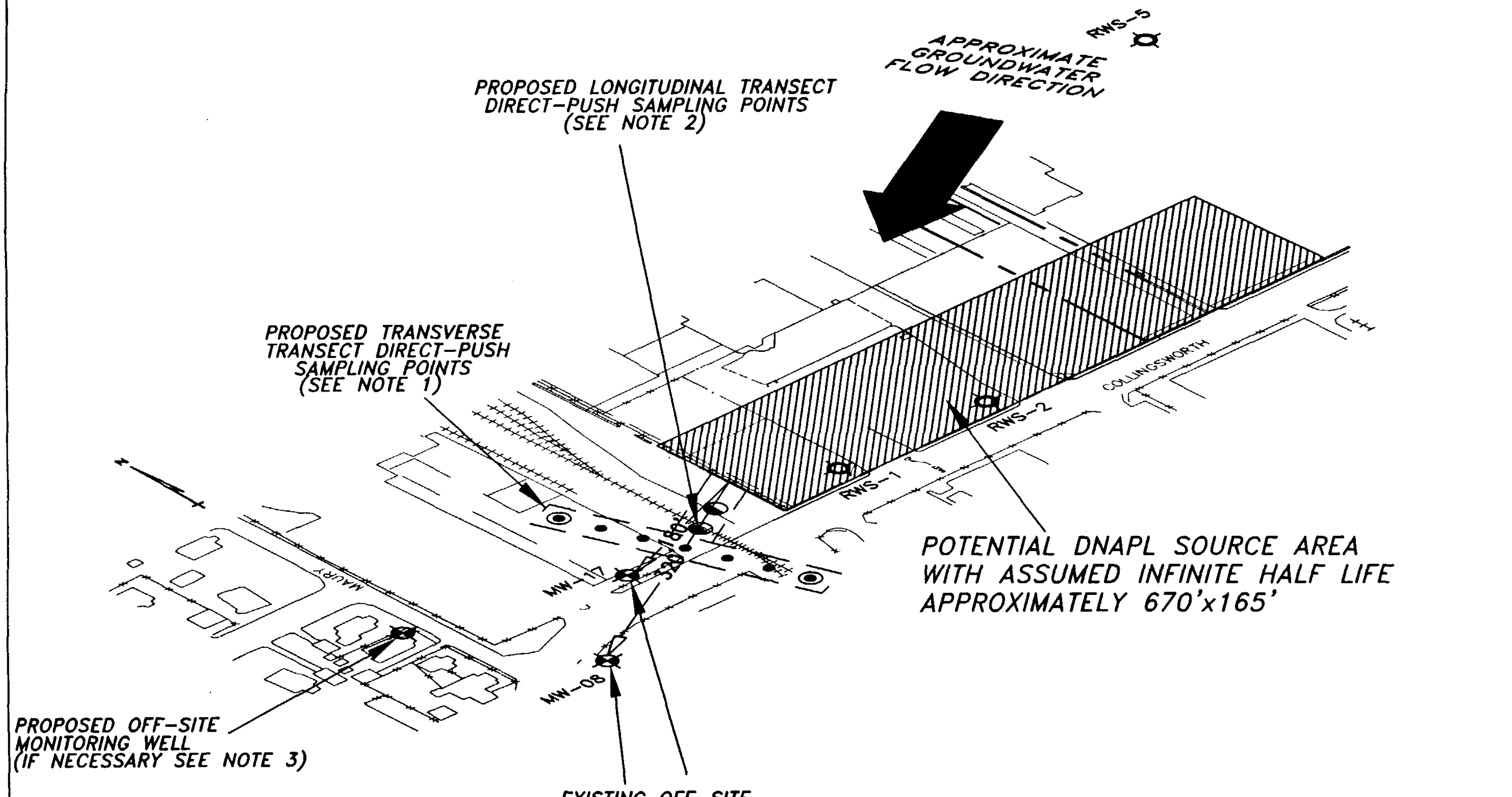

LEGEND:

- EXISTING RECOVERY WELL – PROPOSED DNAPL SAMPLING LOCATION
- MONITORING WELL LOCATION – PROPOSED GROUNDWATER BTEX AND PAH ANALYSIS
- PROPOSED DIRECT-PUSH GROUNDWATER SAMPLING LOCATION
- PROPOSED DIRECT-PUSH SOIL SAMPLING LOCATION FOR TOC
- PROPOSED DIRECT-PUSH SOIL SAMPLING LOCATION FOR MICROBIAL INDICATORS

NOTES:
1) EXACT LOCATIONS OF PROPOSED DIRECT-PUSH SAMPLING POINTS AND PROPOSED OFF-SITE MONITORING WELLS WILL BE DETERMINED FOLLOWING EVALUATION OF ACCESSIBILITY AND THE VERIFICATION OF CURRENT GROUNDWATER FLOW DIRECTION.
2) LONGITUDINAL TRANSECT LOCATIONS TO BE WITHIN PLUME CORE AS DETERMINED FROM TRANSVERSE TRANSECT DATA.
3) NEW MONITORING WELL WILL ONLY BE INSTALLED IF DATA INDICATE THAT THE EXISTING WELLS MW-17 AND MW-08 ARE NOT LOCATED WITHIN THE CORE OF THE PLUME.

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HOUSTON, TEXAS

SOUTHERN AREA PLUME AND AQUIFER CHARACTERIZATION POINTS

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FIGURE 6

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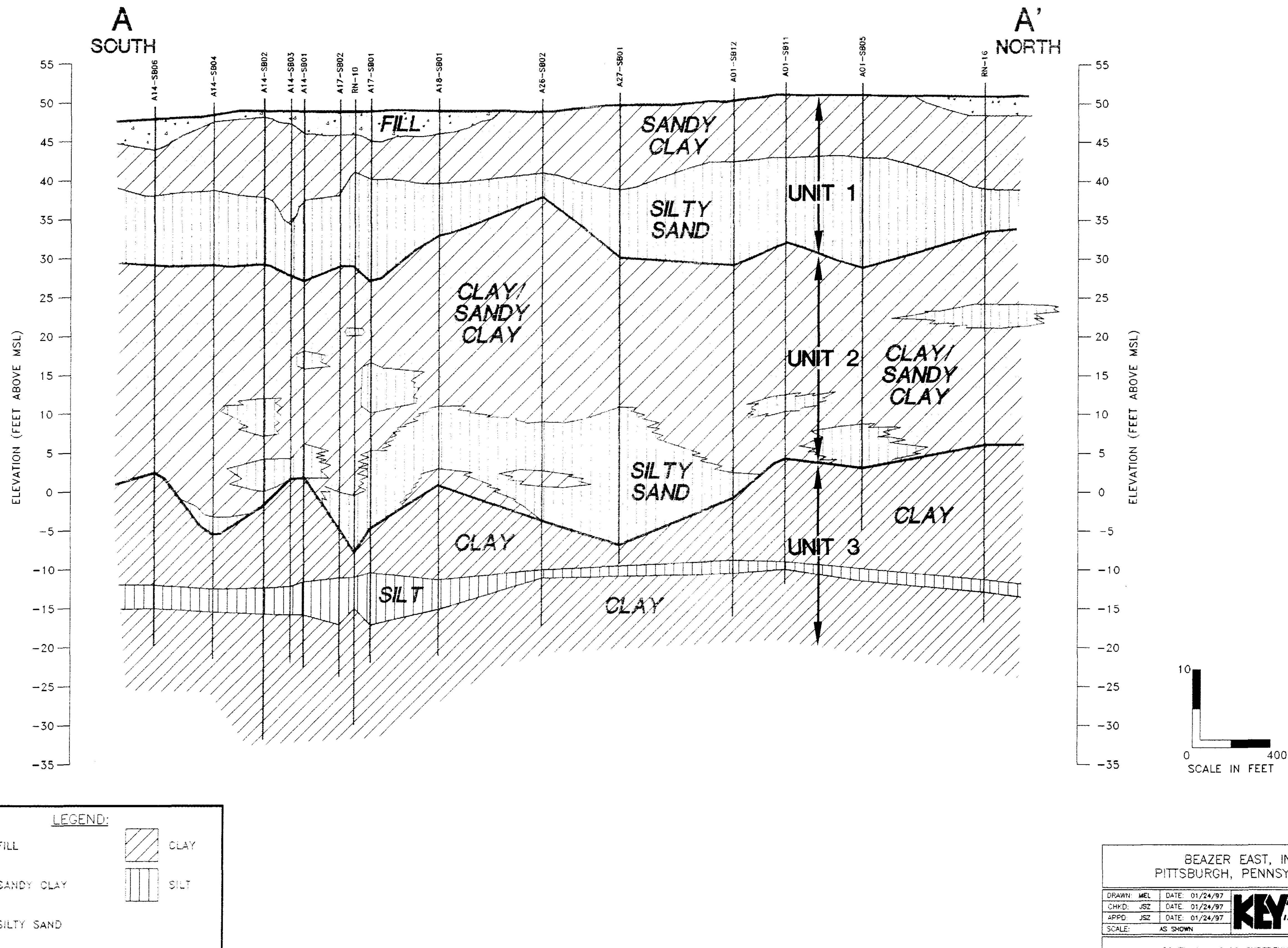

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REFERENCE: FIGURE 4-4C. GENERALIZED GEOLOGIC PROFILE,REMEDIAL INVESTIGATION REPORT, SOUTH CAVALCADE SITE, KEYSTONE ENVIRONMENTAL RESOURCES, INC., JULY 1988.

LOCATION OF CROSS-SECTION SHOWN ON FIGURE 2.

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SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

GEOLOGIC CROSS-SECTION A-A'

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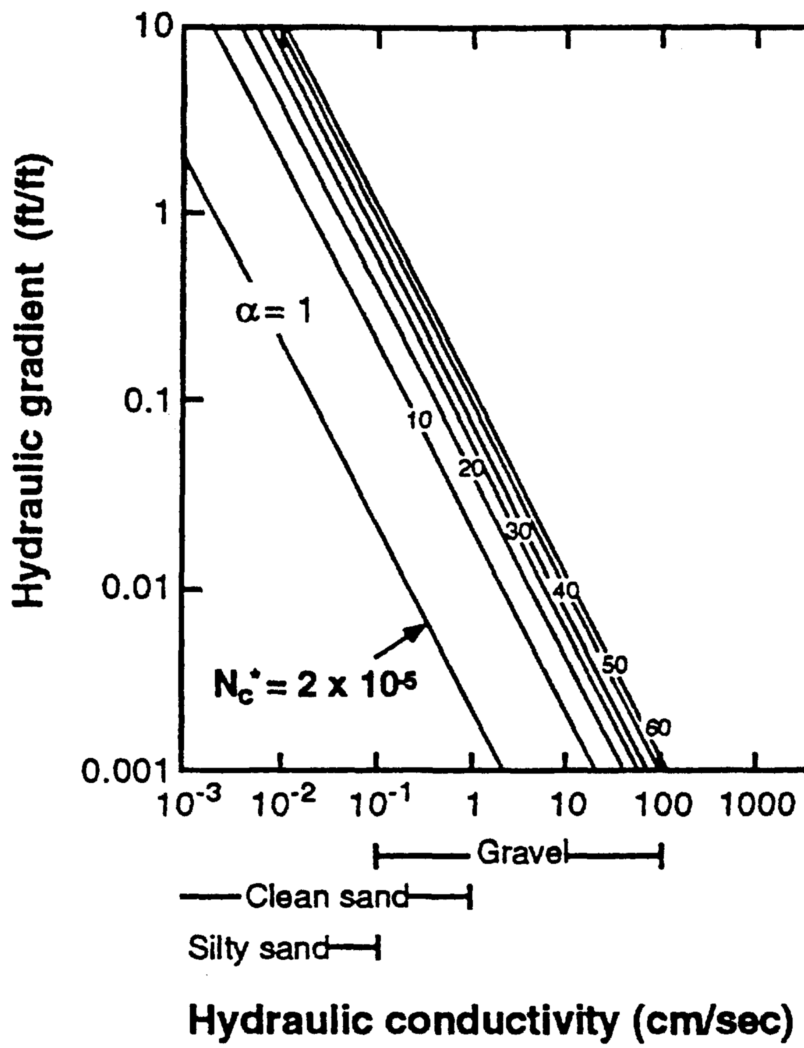
FIGURE 7

000916



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SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

NOTE: ALPHA INDICATES INTERFACIAL TENSION (DYNES/CM).
REFERENCE: WILSON AND CONRAD, 1984.

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INTERFACIAL TENSION, HYRADULIC GRADIENT, AND HYDRAULIC CONDUCTIVITY RELATIONSHIP

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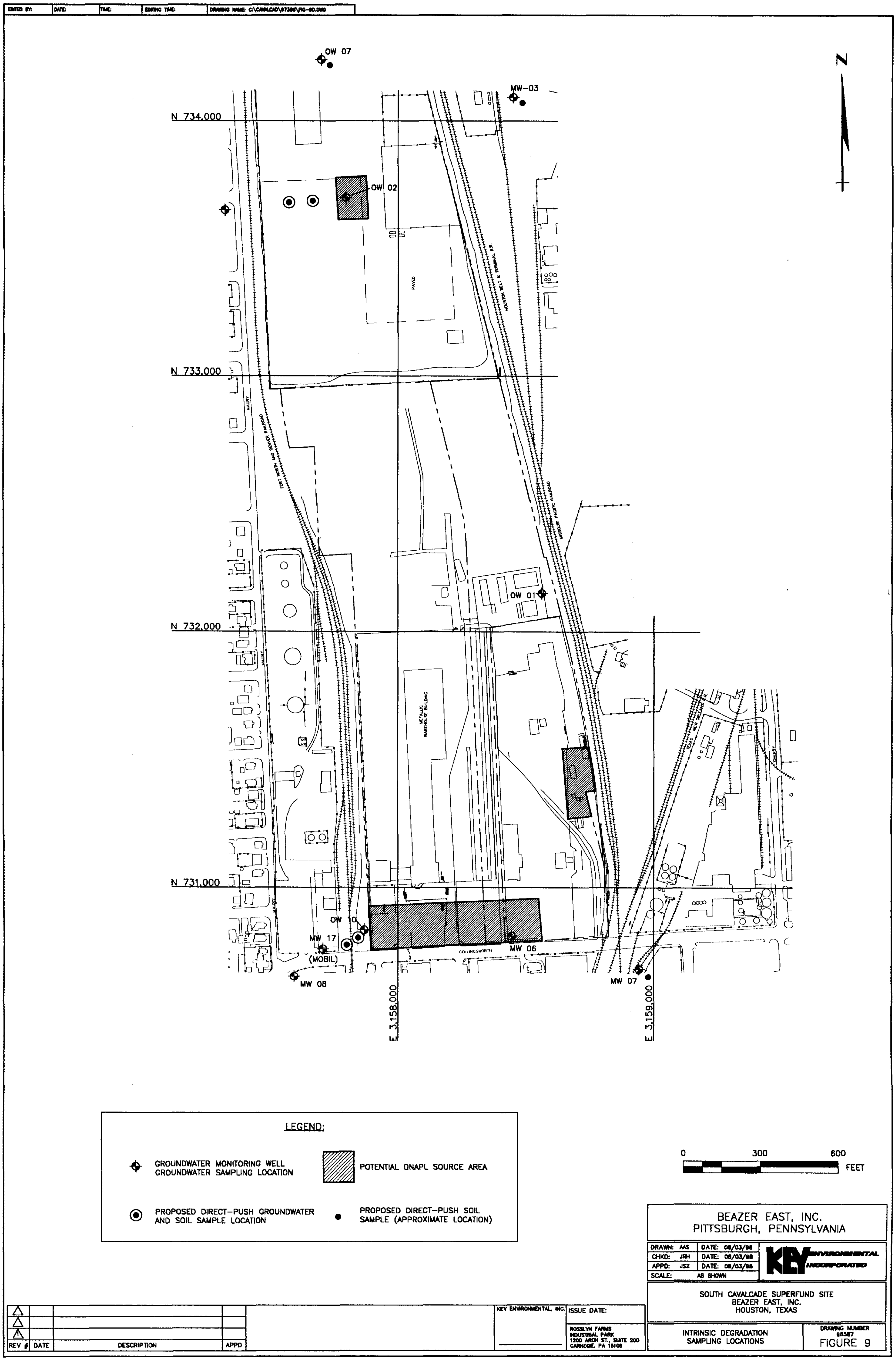
FIGURE 8

D:\CAVALCADE\97386\FIG-07A.DWG

000917



OW 07
MW-03
N
N 734,000
OW 02
N 733,000
N 732,000
OW 01
N 731,000
OW 10
MW 17
(MOBIL)
MW 08
MW 06
MW 07
E 3,158,000
E 3,159,000
LEGEND:
GROUNDWATER MONITORING WELL
GROUNDWATER SAMPLING LOCATION
POTENTIAL DNAPL SOURCE AREA
PROPOSED DIRECT-PUSH GROUNDWATER
AND SOIL SAMPLE LOCATION
PROPOSED DIRECT-PUSH SOIL
SAMPLE (APPROXIMATE LOCATION)
0
300
600
FEET
BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA
SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS
INTRINSIC DEGRADATION
SAMPLING LOCATIONS
FIGURE 9
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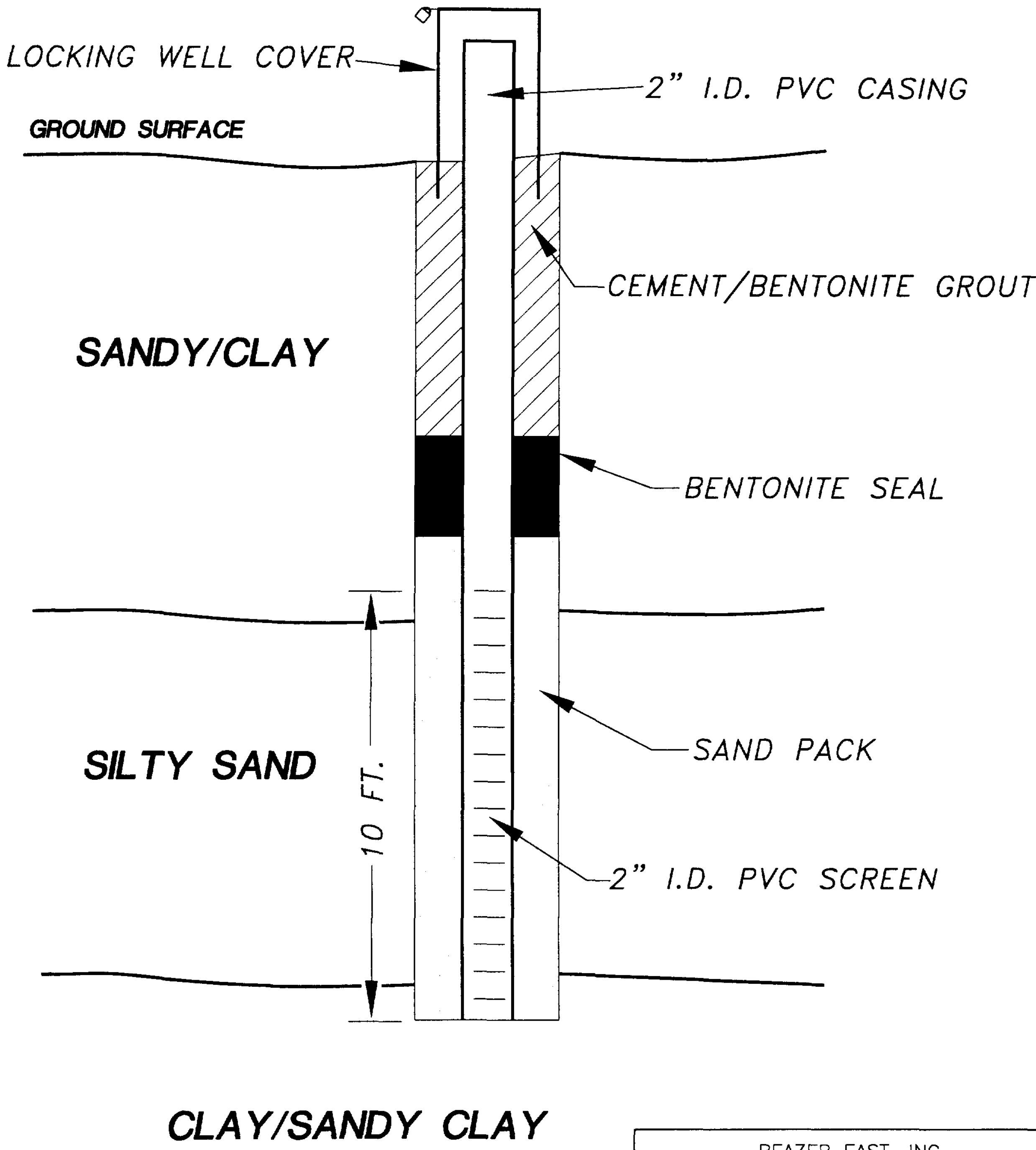
REV # DATE DESCRIPTION APPD

000918



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SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

NOTE: FLUSH MOUNT COMPLETIONS AND COVERS MAY BE REQUIRED BASED UPON PROPERTY OWNER REQUIREMENTS.

KEY ENVIRONMENTAL, INC.

ISSUE DATE:

ROSSLYN FARMS
INDUSTRIAL PARK
1200 ARCH ST., SUITE 200
CARNEGIE, PA 15106

GENERAL MONITORING WELL CONSTRUCTION DIAGRAM

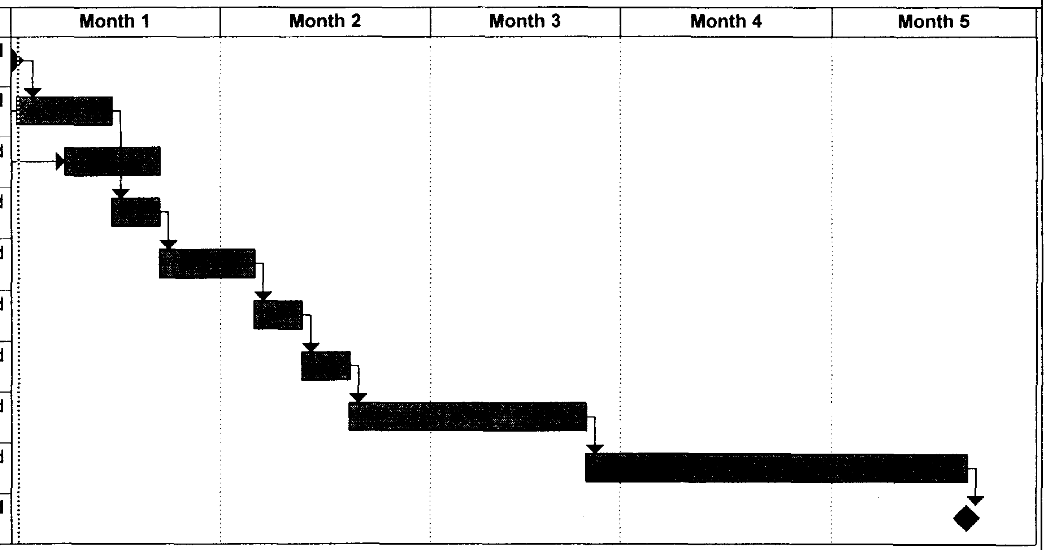
DRAWING NUMBER
97386
FIGURE 10

C:\CAVALCADE\97386\FIG-08.DWG

000919

FIGURE 11 - CRITICAL PATH SCHEDULE
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

ID	Task Name	Duration
1	**EPA Work Plan Approval**	1d
2	Mobilization	14d
3	Suspend DNAPL Recovery System Operation	14d
4	Water Level Measurements	7d
5	Data Evaluation	14d
6	Well Installation/Geoprobe Borings	7d
7	Groundwater Sampling	7d
8	Lab Analysis	35d
9	Data Evaluation/Report Preparation	56d
10	**Report Submittal to EPA**	1d



Project: South Cavalcade
Date: 12/2/97

Task　Milestone

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